COAL RESEARCH

HEARINGS

BEFORE THE

SUBCOMMITTEE ON
ENERGY DEVELOPMENT AND APPLICATIONS

OF THE

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SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

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COAL RESEARCH

TUESDAY, MAY 18, 1982

House of Representatives,
Committee on Science and Technology,
Subcommittee on Energy Development and Applications,
Washington, D.C.

The subcommittee met, pursuant to call, at 1:40 p.m., in room 2325, Rayburn House Office Building, Hon. Don Fuqua (chairman of the subcommittee) presiding.

Mr. Fuqua. The subcommittee will be in order.

Our hearing today on coal research is the first in a series devoted to this subject. We intend in the next several months to hear from industry, colleges and universities, and national laboratories on the present extent and the continuing need for coal research.

Historically, the Nation has used its vast coal resources primarily by direct combustion. Coal has fueled home cookstoves, multimegawatt electric utilities, industrial process steam production, and district heating. As a result, coal production for domestic purposes has expanded to over 700 million tons in 1980. In addition, another 100 million tons were exported to Europe and the Far East.

However, coal can provide benefits beyond those which we presently enjoy, an important one being energy security. But to enjoy these benefits, mining productivity and safety must be improved. Coal must be burned more efficiently and cleanly. We must be able to convert coal to gases and liquids economically and at minimum risk to workers and the environment. To do this, we must pursue basic knowledge of coal physics and chemistry. We do possess some of this basic information and the committee has funded these investigations through DOE for the last 8 years. We view it as a continuing responsibility to further such study programs. In fact, it may be appropriate to expand these basic and applied research programs, taking advantage of increased academic participation, improved laboratory techniques, and sophisticated industrial instrumentation.

So our purposes in conducting these coal research hearings are to inventory those national scientific skills available to coal research, to assess the achievements of the current programs, and to determine the Federal role in future coal research in a time of constrained budgets.

We welcome the witnesses today who have industry, university, and national laboratory background and experience. We look forward to their testimony.

The members of the first panel are Dr. John Sellars of TRW, Dr. Richard Traeger of Sandia National Laboratories, and Dr. Peter Solomon of Advanced Fuel Research.

We will begin with Dr. Sellars.

STATEMENTS OF DR. JOHN R. SELLARS, VICE PRESIDENT AND GENERAL MANAGER, ENERGY TECHNOLOGY DIVISION, TRW; DR. RICHARD K. TRAEGER, MANAGER, GEO ENERGY DEPARTMENT, SANDIA NATIONAL LABORATORIES; AND DR. PETER R. SOLOMON, PRESIDENT, ADVANCED FUEL RESEARCH, INC.

Dr. SELLARS. Mr. Chairman and members of the committee, I am John Sellars, vice president and general manager of the energy technology division in the energy development group of TRW, where all of our company's energy research and development activities are centered. I very much appreciate this opportunity to share with you the vital issue of coal research as an essential, ongoing national goal.

In the statement that I submitted to this committee in March 1982 I indicated the ways in which this Nation is waging and must continue to wage a modern war of independence—energy independence. We must pursue that war to a successful conclusion.

A national failure to continue active programs of coal research may well become the nail for want of which we lose our energy war.

Also in my earlier statement I listed several energy areas to which our company is committed. Allow me briefly to review that list as context for my testimony today.

In the fossil energy area, we are developing advanced utility and industrial coal combustors and gasifiers. Our gravimelt process removes more than 90 percent of the sulfur and ash from eastern and midwestern coal. Our Beacon venture with Sohio promises to convert low-Btu gases to hydrogen, or to cogenerate methane and electric power. We are conducting magnetohydrodynamic combustor R&D and are progressing toward operation of an advanced MHD power train. We are also active in oil-shale development, coalbed methane recovery, and in situ coal gasification—all in support of this Nation's improved use of our domestic resources. To this end, we have invested more than $15 million in fossil energy technologies over the last 6 years, including the construction and operation of our own fossil energy test site near San Juan Capistrano, Calif.

Our principal thrust at TRW has been the innovation and subsequent development of coal-related technologies from fundamental concepts up to the point of commercialization. We have explored heavy media separation for the physical cleaning of coal and are preparing to offer this concept to the Electric Power Research Institute. More than 10 years ago, we pioneered in the removal of pyritic sulfur from coal by chemical leaching. Today, this concept, now termed gravimelt, has evolved to allow removal of more than 90 percent of all the sulfur and more than 95 percent of the mineral matter from coal. With adequate funding, this program will complete bench-scale testing and be ready for a proof-of-concept plant in 1983. Today we are adopting gravimelt to coal-water mixtures and utilizing existing Government facilities at our test site for the flow-loop testing of other coal-water mixtures.

Our Beacon gasification concept, begun several years ago, became a joint venture with Sohio in 1977, and today is a cost-shared program with the Department of Energy. If appropriate Federal funds are forthcoming in fiscal year 1983 and beyond, we will construct and operate a Beacon proof-of-concept plant from 1985 through 1986. Other TRW coal utilization concepts now in the beginning stages of development include: Coal-to-methanol processes, chemical feedstock extraction, and mineral recovery.

In 1975, we began a magnetohydrodynamic coal combustor program using corporate resources. In 1979, we constructed a fossil energy test site to accommodate MHD and other combustion programs resulting from technology spinoff innovations. If Federal support of MHD continues in fiscal year 1983 and beyond, and if the fiscal year 1982 appropriated funds are released, we will deliver a 20-megawatt combustor to Avco in Massachusetts for integrated channel testing this summer; and in 1984 we will deliver a 50-megawatt MHD combustor to a Federal Government facility in Montana for completed MHD power train integration and test.

Again, if future Federal funding allows, we will compete for development of an advanced ash-rejecting coal combustor for industrial and utility oil boiler retrofit, and we will continue to expand our work in the promising field of coal-water mixtures.

To underscore TRW's high level of commitment to coal research—past, present, and future—I would mention our team of 250 scientists, engineers, and technicians exclusively dedicated to fossil energy research. This team is backed by more than 6,000 TRW employees working in the energy field within a total TRW employee population of more than 100,000 persons at sites in all 50 States.

Mr. Chairman, I am sure you are aware of the massive scale of past and present technology transfer from national defense and space programs to the advanced energy activities of today and tomorrow. This transfer has occurred largely through the efforts of the national laboratories and private industry, supported by the Federal Government. Unlike defense and space, however, there has been no comprehensive, coordinated Federal strategy, no coherent set of long-term national goals, in this crucial area of coal research. The need for a true national energy program becomes more critical every day.

The Nation's success to date in energy enhancement and development has been predicated on partnership between Government and industry. Today, some 3 trillion tons of domestic coal reserves await R&D efforts that demand a continuation and expansion of this partnership.

And, Mr. Chairman, this country is going to need to exploit every ton of that coal, using every technique our research and development community can devise.

If the Federal Government's role as a partner in coal R&D is not maintained, many of the promising coal technologies now being evaluated in the laboratory or at bench scale will never reach the marketplace. Quality and productivity will be sacrificed. Future opportunities to meet future needs will be lost.

Apart from the technological aspects of such a defection, there is the sobering reality that much of the Nation's prior investment in developing "centers of excellence" in this field will be forfeited. Industry will be forced to shift dedicated individuals, facilities, and investments, to other endeavors. Furthermore, it is my understanding that such a shift of very significant proportions is about to take place within DOE fossil energy.

Even in the light of current Federal budget constraints, the future of coal research and development cannot be resolved by short-term, quick-fix methods. Federal coal R&D initiatives must become an integral part of long-range national allocation decisions. They must be woven into our future energy strategy, not merely overlaid or imposed upon it.

In conclusion, Mr. Chairman, I will again briefly recall a portion of my statement to you last March. At that time, I noted the vast changes brought about in this country by a long-term research program in agriculture. This program was funded at a low level but lasted for many years—over a century, in fact. It was not a start-stop program, but was consistently pursued over the years. It did not investigate an improved form of corn only to stop once the first ear was harvested. It continued until the crop was ready for planting by farmers. This program had a more profound influence on our present standard of living than any other research program, private or Government, in our history.

I think there is a lesson to be learned from that agricultural program. Energy is almost as fundamental to our modern life as food is, and coal is our most abundant form of energy. In the case of food, we have always been an exporter nation and were never in danger of having someone cut off our food supplies. In the case of energy, however, we are a net importer. Unless we wish to stay that way despite our abundant resources, we must take steps to make these resources usable. This cannot be done overnight, but we can't take a century to do it, either. We must have a steady, consistent program, adequately funded over the long term.

If we carry out this program, we have the possibility of learning how to clean coal until it behaves truly as "solid oil." We can learn to turn it into liquids, even burn it in our automobiles, or we can turn it into electricity without polluting our atmosphere. And we can win the war of energy independence. But we will win only if the Government, equipped with a vigorous Federal program, and industry, with its expertise and resources, remain strong allies.

My thanks, Mr. Chairman, to you and all the members of this committee for your kind attention.

[The prepared statement of Dr. Sellars follows:]

PREPARED STATEMENT OF JOHN R. SELLARS

Mr. Chairman and Members of the Subcommittee on Energy Development and Applications:

I am John Sellars, Vice President and General Manager of the Energy Technology Division in the Energy Development Group of TRW, where our company's energy research and development activities are centered. I very much appreciate this opportunity to share with you TRW's views on the vital issue of coal research as an essential, ongoing national goal.

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Energy Activities

Also in my earlier statement, I listed several energy areas in which our company is active. Allow me briefly to review that list, as context for my coal research testimony today:

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The Future

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My thanks, Mr. Chairman, to you and all the members of this Committee, for your kind attention.

TRW BIOGRAPHY

JOHN R. SELLARS
Vice President and General Manager
Energy Technology Division
TRW Energy Development Group

In 1981, Dr. John R. Sellars became Vice President and General Manager of the Energy Technology Division of the TRW Energy Development Group, Redondo Beach, California. This Division conducts a broad range of activities in energy research, development and engineering.

From 1971 until he assumed his current post, Dr. Sellars was Manager of the Research and Technology Operations at TRW. That position included Lead Executive responsibility for all energy activities in the Applied Technology Division.

Joining TRW (then Ramo-Wooldridge) in 1955, Dr. Sellars participated in re-entry vehicle work for the ballistic missile program. In 1958, he was appointed Manager of the Aerodynamics Department, which was responsible for work on re-entry and launch dynamics; decoy and fusion problems; and special fluid mechanics problems related to ballistic missiles and space vehicles.

Before joining TRW, Dr. Sellars was assistant professor of Aeronautical Engineering at the University of Michigan. While teaching, he engaged in analytic investigations on heat transfer problems, stability problems of flows and problems in the determination of laminar flame speeds.

Dr. Sellars received his Ph.D. degree in Aeronautical Engineering from the University of Michigan in 1952. His thesis dealt with "Some Special Problems in the Stability of Laminar Flows." While a graduate student, he participated in Project Wizard and in research programs, including wind-tunnel work on the pressure distributions over ramjet models burning hydrogen.

Dr. Sellars holds a Master's degree in Physics from the University of Michigan and a Bachelor's degree in Electrical Engineering from New Mexico State University. He is the author of numerous technical papers and holds a patent for a re-entry vehicle design. He received the Sesquicentennial Award in 1967 from the University of Michigan College of Engineering.

Dr. Sellars and his wife Ethel have three children and reside in Redondo Beach, California.

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Mr. **Skeen** [presiding]. Thank you very much, Dr. Sellars. The chairman was called away for a few moments.

I want to take this opportunity to add my welcome to you. It is very refreshing to see another native New Mexican who at least knows where Pajarito Flats is. There aren't many people in the world who know that.

Dr. **Sellars.** Thank you very much.

Mr. **Skeen.** It was an excellent bit of testimony.

I would also like to call now on Dr. Richard Traeger, who is the manager of the geo energy department at Sandia National Laboratories—another New Mexican. We will adopt you, Doctor. We will do the questioning after all the presentations are made.

Dr. **Traeger.** Prior to addressing the three questions on DOE accomplishments, research needs, and the Federal role, I would like to briefly review the diversity of the resource and the technologies needed to acquire the resource.

The massive resource that we have in coal currently consists of peat—which is really a pre-coal—all the way through anthracite. This variation in the coals is one thing that causes many processing problems. We don't understand how these variations affect performance.

For example, about 2 years ago, I was talking to a Lurgi engineer who designs gasifiers. He said the biggest technical unknown that he had for design, scale-up, or operation, had to do with the effect of the variation of the coal—even from a given mine—as it was fed into the gasifier. They didn't know how to design for different coals or what to look for in the coal to prevent operational upsets.

Last week, a design engineer from Exxon, working on an Exxon donor-solvent process, commented that the biggest unknown for the EDS process, in scale-up or design, was the effect of using coal from a different portion of the seam or from a different mine. I don't know the effect of coal variations on combustion, but I would guess the similar uncertainties are true. We really don't understand enough about coal to anticipate how different coals will process in our combustors or reactors.

A second comment is that the technologies required to recover the resource go all the way from exploration and characterization, to mining, to transportation, to combustion liquefaction, and so on. Consequently, if you ask anyone for research that is needed, they will report the research that is needed in their area. If you ask a geologist, you get all the details of exploration. If you ask a person from EPRI, he will give you details of how to convert coal into electric power. If you ask the chemist, he will list all the chemical research needs. All of these are legitimate research needs, but lists like this are so diverse they cannot be readily organized into a coherent program.

In the fifties and sixties, there was a fair amount of coal research in this country. It went on at Penn State, the University of West Virginia, Wyoming, the Energy Technology Center, and many others. This diverse research let everyone play in their own sandbox and do their own thing. When we reached the problems in 1973 and said, "Crash, what can you do to build a liquefier or gasifier?" it turned out that the available data were not adequate to design a gasifier. Not that the research wasn't good; it just wasn't put together in any usable form.

DOE accomplishments: I am sure DOE could provide an infinite number of lists, but I will make just one comment. Last week at the EPRI meeting, there were reviews of the H-coal liquefaction process, of the Exxon donor-solvent process, and of the advanced concept called integrated two-stage liquefaction. In those scenarios, we are talking about reaction pressures of 1,500 to 2,000 psi. After those discussions, a German engineer reviewed their direct liquefaction effort where they are down to 4,000 psi. Now, going from 1,500 to 4,000 psi is significant in the size of plant, welding needs, pump capacities, and all other technologies.

So, just looking at the overall DOE accomplishments in the liquefaction area, we are ahead of the Germans by a factor of 3, if nothing else, in pressure. We also have a better distillate yield and a better capability for distributing products.

The next question, "What should be done?" I think has to be addressed by first discussing the Federal role, because one needs a context to discuss research needs. At least as I visualize the Federal role, there are three areas: security, resource management, and environmental or populace protection.

Let me talk about security. If we look at a true emergency, that is, should there be a war or embargo, or if we take the next step and say we want to be energy independent, the obvious problem is liquid fuels. So the question is: Could you do something on liquid fuels? Right now, if put to the test, I see no reason why we could not design and build liquefaction plants. Although plants would not operate optimally, we could design and build an EDS plant, an H-coal plant, an SRC–2 plant, or could use indirect liquefaction through the Texaco gasification to methanol followed by the Mobil methanol-to-gasoline process.

What is holding back the building of such plants? Two things: economics and environment. If I look at evolutionary research in these processes, and look at the way costs are spread through the plant, I don't believe that research will have any significant impact on economics of the current systems. That is my personal opinion, and people will argue with it.

There is going to be little work done by industry on environmental research, except as needed to meet regulations.

The third area in security has to do with availability of technology. With the DOE pulling out of the liquefaction program, essentially everything is shutting down. EDS is going to blade off their Baytown plant, and the rest of the industrial facilities are closing up. Japan is going like gang busters. So I would bet that in 10 years we will buy our technology from Japan if we get out of the business completely.

Let us consider the national role of resource utilization and look at the resources that are available. For example, in the eastern underground mines, 50 percent or 60 percent of the coal remains underground as pillars or ribs to support the overburden. So the question to be addressed is, Are we going to throw away that 50 percent, or is there any method to make that 50 percent available to this Nation?

The coal in deep seams may be recovered by situ gasification or possibly a process of in situ liquefaction. I believe there should be advanced research to determine if we can ever make the peats available. Are they best for liquids, or for gases, or for combustion? The research would not be to design systems that would be commercially competable, but to determine if there are systems potentially available that can be used to recover these fuel resources.

The third area is environment, which is obviously a Government role, because it covers all States and international boundaries. The traditional environmental role has been, and should remain, to identify the dangerous species, the carcinogens, etc., and determine ways to regulate or monitor such species. However, I submit that a good basic coal research program ought to have a major goal of developing new coal processes that don't produce hazardous materials. Right now the research isn't oriented that way, but I believe the Government could have a basic research program with a focus of producing fuels that don't contain the carcinogens. Some of such R&D results are evident in combustion now, where there are catalytic systems for low-temperature combustion that limited generation of NOX.

I would propose that coal research ought to be done in the environmental area, but emphasize an understanding to produce liquids and fuels that do not have or produce the carcinogens and pollutants.

Finally, the third question on research needs. First, I believe the research should be focused. A generic research program with a geologist doing a little bit of coal geology, a chemist doing a little bit of coal chemistry, and another doing a little bit of coal physics, will provide elegant, publishable, very good research. When you get it all together it won't be useful. Somehow we have to provide a focus to the research.

The second need in coal research is to develop an understanding of chemistry and physics on how coal behaves in processes so that, in an emergency, we can have an EDS process, an H-coal process, or a gasification process; and that when they pull coal out of another mine, we can be assured the equipment won't plug back up, or blow up.

With those scenarios, I see a very fundamental research role for the coal, with a focus (and Dr. Sellars proposed some focuses).

The final comment I would like to make is that I can visualize, as a dreamer and as an engineer, in the future—and this was triggered by an article in the Chemical and Engineering News—the development of a coal refinery. If we look around this country now, we see petroleum refineries. The refineries down in Houston are using oil crudes out of Oklahoma, East Texas, West Texas, Arabia, Indonesia, and Alaska. From this mixture of crudes, they are producing jet fuels, or heating oils, or whatever is in demand.

Similarly, coal refineries that would be built in the East and in the West, could use different coals—the Pittsburgh coals, the Illinois coals, the Ohio coals, the West Virginia coals, to provide an appropriate mix of products, from chemicals to polymers, to gasolines, and so on. To me, that is a dream of the future and I think we can get there. Thank you.

[The prepared statement of Dr. Traeger follows:]

TESTIMONY ON COAL RESEARCH NEEDS

to the House Subcommittee on
Energy Development and Applications
May 18, 1982

R. K. Traeger
Sandia National Laboratories
Albuquerque, New Mexico 87185

Congressman Fuqua, I appreciate the opportunity to present my thoughts on coal research including achievements of the DOE programs, new directions for coal research and the Federal role. Brief reviews of coal resources and coal related technologies are also presented to provide perspective for the subsequent discussions. A summary as this can only address generic research areas, but specific details on past accomplishments or needed research could be further developed if you so desire.

Coal Resources

The extensive U.S. coal resources have been described in many documents and are summarized in Table 1. The point to be made is that the different coal types require different technologies for recovery, use and environmental protection. Thus, research needs must be categorized according to coal types as well as the individual technologies noted in the next section.

A second point to be made is that variations in coals of the same type (frequently from different locations in the same coal mine) can have major effects on the combustion, liquefaction or gasification of that coal. We do not understand these variations, nor can we predict how much variations will effect subsequent processes.

Table 1. United States Coal Resources

Coal Type	Remaining Identified Resource Billion Tons
Anthracite[1]	20
Bituminous[1]	747
Sub-bituminous[1]	486
Lignite[1]	478
Peat[2]	120

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[1] G. L. Baughman, Editor, Synthetic Fuels Data Handbook, Cameron Engineers, Inc., Denver, Colorado, p. 153 (1978).

[2] V. K. Mathur, Coal Powers, Its Promises and Problems, Energy Communications, 7(3), 205 (1981).

Coal Related Technologies

Development and utilization of coal involves technologies ranging from geophysical exploration techniques to evaluating the implications of acid rain. An abbreviated list of activities and technologies are noted in Table 2. Many important, good research projects could be identified for each of the areas; any research list will reflect the background and interest of the individual providing the list. Development of any coal research program should therefore include a continually updated systems approach to identify the research areas that will have the maximum impact on national needs.

Since this discussion is oriented toward DOE programs, I have chosen not to include comments on exploration and assessment (a USGS responsibility) or on mining (a Bureau of Mines responsibility).

Table 2. Stages in the Development and Utilization of Coal

Stage	Activities	Technologies
Exploration	Location and Size	Geosciences, Drilling
	Characterization	Coring, Chemical Analyses, Petrology
	Environmental Evaluation	Subsidence, Aquifer Definitions, Mine Safety
Recovery	Mining	Rock Mechanics, Engineering, Machine Design
	Cleaning	Size Reduction, Flotation, Separation Processes
	Environment	Mine Safety, Subsidence
Transportation	Railway and Truck	Engineering
	Oil or Water Slurry	Fluid Dynamics, Slurry Handling, Surface Sciences
Utilization	Combustion	Many chemical, physical and engineering sciences
	Gasification	
	In Situ	Chemical, physical, engineering and geological sciences
	Surface	Chemical, physical and engineering sciences
	Liquefaction	
	Indirect	Chemical, physical, and engineering sciences
	Direct	
	Environmental	Chemical, engineering and geosciences

DOE Coal Research Achievements

As you are well aware, coal research in the past 50 years has periodically received Federal emphasis followed by long periods of almost complete neglect. This cyclic emphasis then requires an initial large expenditure of time and monies to resurrect past history, to identify applicable techniques and tools developed since the past research, and to repeat many of the learning mistakes. This relearning occurred in the ERDA/DOE years (with current industrial and Government trends suggesting this learning cycle will be repeated in another 20-50 years).

Significant scientific contributions have been made when the research need was recognized and scientists who became aware of the problems agreed to branch into the dirty, complex, very difficult research of coal sciences. This research has been supported by ERDA/DOE, EPRI, state and other agencies in conjunction with private industry. I do not believe it would be useful, nor am I in any position to list the multitude of recent accomplishments in the coal sciences. However, I would like to note some major results for which DOE funding was wholly or partially responsible:

- Mobil's methanol-to-gasoline shape selective catalyst which not only has current commercial applications, but has triggered a new wave of catalyst research.
- Entrained bed gasifiers that are potentially capable of handling caking and non-caking coals (Lurgi processes use only non-caking types).
- Direct liquefaction processes that operate at 1/5 the pressure of the original German processes.
- Identification of a truly advanced liquefaction concept (Integrated Two-Stage) that could have a significant impact on the future use of coal.
- Reassessment of the availability and applicability of the U.S. coal resource.
- Application of modern techniques (Mossbauer, x-ray fluorescence, nuclear magnetic resonance, laser plume spectroscopy, etc.) to study coal and the use of these to provide information on coal reactions.
- Identification of potential health hazards introduced by some coal liquids.
- New materials (carbides, borides...) developed for use in highly erosive environments.

- Engineering improvements in pumps, compressors, valves and other equipment for high temperature or solids handling applications.
- New diagnostic concepts that have process control applications in many industries.

Other areas could be listed and multiple detailed accomplishments could also be given for each of the results noted above. Less tangible, but perhaps a more important product of DOE funding, is the renewed academic and industrial interest in the coal sciences which should continue to provide new insights and contributions to the use of the national coal resource.

The Federal Role

Federal responsibilities I chose to address for considering coal research needs include National Security, Resource Utilization and Environmental Protection. The following comments are based on my individual perceptions and do not necessarily reflect the opinions of Sandia National Laboratories or of the Department of Energy.

National Security

The U.S. domestic and military transportation systems rely entirely on liquid fuels. Emergencies such as war or embargoes that would limit this supply are of national concern. A second security question is related to the balance of payments with long-range and increasing dependence on the oil exporting nations. A third concern is the potential shift of all the advanced technology to countries such as Japan and Germany who are emphasizing coal process research.

In a national emergency, liquid fuel needs would be met in part by reallocation of domestic petroleum and use of stored reserves. Shale oils, because of their chemistry, are suitable for providing additional diesel and jet fuels. Coal liquids would be applicable for internal combustion engines, chemicals and explosives. Technologies now exist (SRC-II, Exxon Donor Solvent, H-Coal, Indirect Liquefaction) that could supply needed coal liquids although the plants would not operate in an optimum mode. Major concerns would be the availability of materials plus fabrication facilities, and of engineers and scientists who understand the nuances of coal processes.

Continued development of coal processes to meet future U.S. needs and to counter petroleum imports is currently limited by economics and environmental concerns. Since no one operation dominates the cost of coal gasification/liquefaction systems, evolutionary R&D (best done by industry) has low probability of providing a significant cost reduction. However, the environmental uncertainties must be addressed by the government in order to assess hazards, define regulations and identify acceptable commercial processes.

With the envisioned decrease of U.S. interest in coal research and intensification of work in Japan and Germany, our nation could readily reach the stage where we would have to rely on technology from outside this country. This external reliance could have serious implications in national security.

Resource Utilization

Evaluation of resources to plan for future U.S. needs and exploitation control to maximize resource utilization are clearly Federal roles. The evaluation role is under the purview of the U.S. Geological Survey and will not be discussed further. Areas of uncertainty in resource availability or applicability should be addressed, possibly involving R&D. Examples: What energy needs can be or should be met by peat? By the lignites? Can we ever use half of the coal left in underground mines as pillars to meet future energy demands? Are there new mining or in situ processes that could recover resources that now appear unavailable? The purpose of research in these areas would be to evaluate the technological feasibility of extending the available resource, not to develop commercially economic processes.

Environmental Protection

Understanding, control and monitoring of undesirable environmental effects that impact many states or nations is clearly a Federal role. Environmental concerns extend through the entire coal utilization cycle from the impact of exploration techniques on wildlife, to subsidence and safety during mining, to water and air pollution during processing, to the international concerns of acid rain. Historical emphasis has been on identifying effects of pollution, monitoring the extent of such pollution and developing regulations tc protect the populace. These activities should continue, particularly in areas of potential global impact such as acid rain and the CO_2 greenhouse question.

However, I submit that a basic understanding of coal chemistry, the combustion process, liquefaction and gasification mechanisms and other fundamental coal reactions is essential to find methods to eliminate or minimize the identified hazards in the coal processing itself. This research thrust is not financially supported by industry because of no visible future profit. Such a thrust would not compromise current industry research in areas of scrubbers, cyclones, etc., needed to meet Federal and state regulations.

Directions for Coal Research

As mentioned earlier, coal research needed for exploration, resource characterization and mining will not be discussed although continued studies are needed in those areas. Also, generic needs to maintain academic expertise and a "pure" research base are the responsibilities of other Federal agencies such as the National Science Foundation and the DOE Basic Energy Sciences effort. Thus, the research I will address emphasizes studies using coal, coal products and coal systems to meet national needs as previously described.

Also, you are well aware of the numerous other extensive studies made by prestigious scientists or groups such as the American Physical Society[3], the FERWG Committee[4], the ERAB Committee[5], the Gorbaty group[6], and V. K. Mather[7]. I have little to add to their conclusions and consequently have chosen to list those areas I consider most important and in my priority sequence.

Priority I -- Fundamentals

- Coal Structure, Chemistry and Physics

  Objective: Understand the organic and mineral constituents in various coals in terms of effects on behavior in combustion, pyrolysis, gasification, liquefaction and cleaning. Identify potential uses for each coal and possible environmental concerns during use.

  Areas of Study: Structure; porosity; initial surface reactions; mechanical behavior; mechanism of formations of carcinogens, NO_x, SO_x; chemistry of organic and inorganic portions.

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[3] Pines, D. (Editor), Report to the American Physical Society by the Study Group on Research Planning for Coal Utilization and Synthetic Fuel Planning, Reviews of Modern Physics, 53 (4), Pt. 2 (October 1981).

[4] Penner, S. S., and others, Research Needs for Coal Gasification and Coal Liquefaction, Energy, 5, p. 1091 (1980).

[5] Foster, J. S., and others, Federal Energy R&D Priorities, Report of the Energy Research Advisory Board (November 1981).

[6] Gorbaty, M. L., and others, Coal Science: Basic Research Opportunities, Combustion, 51, p. 12 (April 1980).

[7] Mather, V. K., Coal Power, Its Promises and Problems, Energy Communications, 7(3), p. 201 (1981).

- Transport and Physical Properties

    Objective: Provide a data base for engineering design and reaction dynamics needed to develop new process concepts and understand basic reaction mechanisms.

    Areas of Study: Physical properties; diffusion; swelling; softening mechanics; elastic and plastic behavior; pore structure; adsorption physics; non-Newtonian flow.

- Environmental

    Objective: Understand the mechanisms of formation of carcinogens, NO_x, SO_x for possible mitigation of the undesirable species.

    Areas of Study: Surface physics and chemical reactions; kinetics; thermodynamics.

Priority II -- Primary Processes and Products

- Revolutionary Combustion, Liquefaction and Gasification Concepts

    Objective: Identify new processes that could markedly change the processing and use of coal.

    Areas of Study: Low temperature reactions; gasification in solution; dissolution by highly polar compounds; catalytic combustion; microwave and ultrasonic effects.

- Physical Processing

    Objective: Develop unique processes for preparing a clean or modified coal for subsequent use.

    Areas of Study: Coal-mineral interactions; mineral reactions; coal fragmentation; surface physics; crushing and grinding; selective separations.

- Properties of Coal Derived Products

    Objective: Understand potential health and disposal problems associated with coal liquid and gaseous products.

    Areas of Study: Chemical characterization; toxicity studies; decomposition mechanisms; kinetics.

- Multiphase Flow

  Objective: Develop the mathematical and data base needed for the design of process equipment.

  Areas of Study: Three-phase flow; solids-gas flow; non-Newtonian systems; viscosity measurements; heat transfer rates; flow regimes.

Priority III -- Secondary Processes and Products

- Novel Catalysts

  Objective: Develop catalysts that allow reactions at low temperature or provide unique product distributions.

  Areas of Study: Shape selective catalysts; homogeneous catalysis; surface physics and chemistry; kinetics; thermodynamics.

- Coal Product Upgrading

  Objective: Develop energy efficient methods to minimize environmental concerns and provide unique product slates.

  Areas of Study: Reaction chemistry; analytical procedure development; kinetic; catalytic mechanisms, gas and liquid clean-up.

- In Situ Processing

  Objective: Develop adequate understanding and new concepts for concerting the coal in its natural, in situ environment.

  Areas of Study: Thermomechanical properties of coal systems; geostructure of thin coal beds; unique process concepts; heat and mass transport modeling.

- Ash and Solid Residue Handling

  Objective: Identify potential uses (e.g., mineral recovery) or limitations to the utilization or disposal of process solid residues.

  Areas of Study: Inorganic chemistry; petrography; leaching; structural stability; solids handling.

Priority IV -- Support Research

- Coal Bank

  Objective: Maintain a set of representative coal samples and a summary of past research on those samples for use by the scientific community.

  Areas of Study: Data retrieval; characterization; petrography; library science.

- Materials

  Objective: Identify and resolve materials limitations unique to coal processing.

  Areas of Study: Corrosion; erosion; stress cracking; fracture toughness; high temperature behavior.

- Dynamics of Fluid Beds

  Objective: Develop data and understanding for the design of fluid or entrained bed combustors, gasifiers or other processing equipment.

  Areas of Study: Fluid dynamics; heat transfer; fluidization of solids; kinetics.

- Diagnostics

  Objective: Develop analytical or process control tools needed for coal understanding and processing.

  Areas of Study: Diagnostics; mechanics; transport physics, instrumentation.

Priority V -- Evolutionary Concepts

Current combustion, gasification and liquefaction concepts are constrained in many areas by a lack of understanding of the process dynamics, inability to extrapolate processes from one coal to another, materials and instrumentation limitations, yields, hydrogen utilization and thermal efficiency. Good research in selected areas could provide significant improvements in the current process concepts.

Conclusions

Discussions of this paper and interactions with the coal research community lead to the following conclusions on the future and needs for coal research.

- Resource -- The coal resource is immense and a plan for optimum use of the peat to anthracite supplies should be developed and evolved.
- Current and Future Research -- Coal research efforts in industry are rapidly decreasing and work at universities, Technology Centers and National Laboratories is directly dependent on Federal funding. Industrial emphases will shift to combustion and coal cleaning with limited development of gasification concepts.
- Human Resource Base -- A cadre of scientists and engineers knowledgeable in coal processes needs to be maintained for evaluating environmental effects of coal use and for a design base in times of national emergencies.
- Basic Coal Sciences -- A major effort in understanding coal structure, chemistry and physics as related to behavior in processing is essential to developing environmentally acceptable processes and to identify revolutionary concepts for utilization of the national resource.
- Federal support of coal research is required to assure national needs of security, environmental protection and resource utilization are met.

As the U.S. energy base shifts from petroleum to coal, one can envision the development of a new coal refining industry. Such an industry would probably not look like current petroleum refineries, but, similar to oil refineries, would be capable of accepting a variety of feed stocks (peat to anthracite) and providing a product slate (fuels, chemicals, graphite, heat) to meet varying seasonal or national needs. This potential coal refining industry could optimally use the U.S. resources of coal and people. Evolution of such an industry can only occur if the data base on coal, coal properties and coal behavior is adequate to trigger the innovative thinking that has developed many U.S. industries.

Biographical Sketch

RICHARD K. TRAEGER
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Education

1954	University of Wisconsin, Bachelor of Science, Chemical Engineering
1958	Case-Western University, Master of Science, Chemical Engineering
1965	University of New Mexico, Doctor of Philosophy, Engineering

Professional Experience

Sandia National Laboratories (1963-present): Management of geothermal and synfuel research and development programs including activities in drilling, well completions, instrumentation, diagnostics, chemical processing and field operation. Research in coal liquefaction, oil shale processing, advanced electronic processing, polymer behavior and structural foams.

University of New Mexico (1963-present): Adjunct Professor, Thermodynamics, materials.

University of New Mexico (1959-1963): Instructor in Chemical Engineering. Taught five courses per semester; advisor to 70 students and two student organizations; several College and University Committees.

B.F. Goodrich Chemical Company (1954-1958): Process design of chemical plants and research on antiozonants, polymerization catalysts and other chemicals.

Affiliations

Registered Professional Engineer in Ohio and New Mexico
American Institute of Chemical Engineers (Secretary of Fuels and Petrochemicals Division)
Institute of Electrical and Electronic Engineers
American Association of Engineering Educators
American Chemical Society
National Academy of Science/National Research Council -- Member of Continental Scientific Drilling Committee

Publications and Presentations

15 journal articles
25 professional papers
Program Chairman of International Conference on Geothermal Drilling and Symposium on Synfuels
Over 40 technical Sandia publications

Mr. FUQUA [presiding]. Thank you very much, Dr. Traeger.

Dr. Solomon.

Dr. SOLOMON. Mr. Chairman, members of the committee, my name is Peter Solomon. I am the president of Advanced Fuel Research, Inc. I am a physicist who has converted to being a coal scientist.

Advanced Fuel Research is a small R&D company. We do work in coal, oil shale, and biomass, and we have a stated objective which I think gets at the heart of what ought to be done in coal research. Our objective is to improve the characterization of raw materials and provide the ability to predict and model process behavior. I obviously have a strong interest in the question before this subcommittee.

I would like to address five points in my testimony.

Point No. 1 is that coal research is in desperate need of support.

Point No. 2 is that adequate support is not going to come from the private sector.

Point No. 3 is that support of coal research and development is a very legitimate function of the Federal Government.

Point No. 4 is that the past Federal support of coal R&D is producing results, and I think, given sufficient time, will start to provide a sound base for coal-processing technologies.

And point No. 5 is that for the future, we need continued support to make coal science a sound foundation for coal technologies.

Point No. 1, coal science is in desperate need of support. Why do I say this? At the present time there is no accepted model for the chemical structure of coal or its chemistry in a process. The practical implications of that ignorance are that in designing coal processes we can't answer simply questions like how big should the coal reactor be, how long should the coal be in the reactor, and what happens if we change coal? We can't answer the fundamental questions in designing a process, and we certainly can't answer the more difficult questions of what detailed chemistry is going on inside the reactor.

My second point is that adequate support for coal science cannot be expected from the private sector. I would now like to refer to my written testimony and quote:

> The task of making coal chemistry a predictive science is formidable. To make progress it is necessary to utilize fully the scientific resources in the country. This means using the ideas, scientific expertise and facilities of all appropriate disciplines from universities, industrial laboratories, national laboratories and small research companies. It also requires free dissemination of research results, freedom from the requirement for immediate product-oriented results, a long-term steady commitment and cooperative programs among many laboratories.

If we rely on the private sector alone to support coal research, we will not have free dissemination of the research results. We will have little freedom from short-term, product-oriented needs, and we will have little cooperation among many laboratories. We will lose some of the most innovative programs from universities, national labs, and many industrial labs that don't have a very strong commitment in the commercialization of coal but do have unique facilities and talents that can be brought to bear effectively on the coal science question.

I should also mention that we will lose programs from the small research and development companies, like Advanced Fuel Research. Of course, you might well ask whether this would be a significant loss. Obviously, I believe the answer is yes, it would be a loss.

Let me give you a little information about the kind of work we are producing. We are presently introducing new measurement techniques to characterize coal and monitor coal processes. We are developing an understanding of coal structure and how that structure relates to the way coal comes apart, that is, its chemistry. And, importantly, we are freely disseminating the information.

If you ask the large companies whether this sort of thing is important, I am not sure that they would really admit it is. But I have had a very heavy travel schedule within the last 2 years, and let me just indicate who I have been visiting, on invitation, to tell about our contributions to the field: I have been to Exxon twice, I have been to Mobil twice, I have been to Chevron twice, I have been to Occidental Research, Bethlehem Steel, and Rockwell. I have been to Sandia, the U.S. Bureau of Standards, Penn State University, Iowa State University, Brigham Young University, and several more.

The third point is that the support for coal research and development is a legitimate responsibility and function of the Federal Government. This point has been addressed before. It is very simple. The coal research program will address national priorities. It addresses national security by supplying a secure supply of energy. It addresses economic stability by reducing our flow of dollars outside the country, and also by providing a competing energy source which will help hold down oil prices. Of course, it also addresses the environment by providing strategies for controlling pollutants from coal utilization.

The fourth point is that Federal support is producing results. I think one of the important things that has occurred from the Federal support is the new people, the new disciplines, the new facilities, and the new techniques which have been brought into the field. I have enumerated these in my written statement and they have been enumerated in many, many other documents.

All of these things are starting to supply a better understanding of the basic structure of coal, a new understanding of the chemistry of coal, and what is happening when coal is processed. We need more time in order to bring that new understanding to the point where we have a sound foundation for technology.

The fifth point gets to the question which I think this hearing is really about, and that is, where do we go from here? The first thing that I think we need to define is an agreed-upon definite goal. I have suggested a goal in my written statement. That goal has got to be the development of the technologies and understandings so that we can characterize this enormous resource and be able to predict the way it is going to behave in a process. That kind of characterization is going to allow us to improve existing processes and develop many important new processes.

Second, we need a mechanism to implement the goal. The AR&TD program within fossil energy probably comes closest to addressing the basic needs required to make coal science a foundation for coal technology. But I think that the goal has got to be reiterated and stated so that the AR&TD program can be directed toward, it. I also think the AR&TD program needs increasing coordination amongst its gasification, liquefaction, and combustion branches, and I think that the AR&TD program would benefit from increased input from the scientific community outside DOE.

Last night I read part of the Sunset Review that pertains to the AR&TD program, and I got through three pages of the Sunset Review and I couldn't disagree with any of the things the administration said about the AR&TD program. Let me quote one paragraph from near the end of the review.

> The AR&TD program is an integral and necessary part of any conceivable research and development program on fossil energy, because it provides the general technical knowledge and occasionally breakthrough ideas that carry such a program to successful completion. The federal government's role in supporting AR&TD is justified by an inherent high-risk and long-term nature of such activities.

I couldn't agree more with that statement. The problem is, in the 1983 budget. Where do we go with this very successful program? The Sunset Review says that program objectives will change somewhat with the termination of the university coal research activities, as well as activities in the areas of improved heat exchange, instrumentation and control, engineering analysis, technology-base synthesis, which will be phased out in 1982. The rest of the activities will continue at reduced funding, although it will have an increased importance to the rest of the fossil energy program. This increased importance means that the AR&TD program was only cut by two-thirds, while the rest of the fossil energy program was cut by about three-quarters.

Well, what level of support might be appropriate for coal science? If you look at the national average for industrial support of research and development, that average is about 2 percent of sales. If you examine the fossil fuel industry, which is about a $400 billion a year industry in sales, it spends only one-fifth of the average 0.4 percent on R&D. That number is only second to the tobacco industry in being lowest on the list.

If we use 2 percent of just the coal sales in this country alone, we ought to have an R&D activity in coal research of about $600 million. I believe the 1982 level of $56 million in the AR&TD activities was clearly too low and we should increase that level.

Finally, in conclusion, we seem to have today an oil glut, and one of the nice features of that oil glut is we do not have to rush coal technologies into the marketplace. We therefore have a temporary reprieve in which we can improve and apply coal science so that new coal technologies, when they finally have to be introduced to the marketplace, are cleaner, more efficient, more economic, and are based on enough understanding so that we can predict what is going on in a process.

I would like to thank the committee very much for inviting me here to express my views.

[The prepared statement of Dr. Solomon follows:]

STATEMENT OF

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I. CURRENT STATE OF COAL SCIENCE

The use of coal may have originated as early as 1000 B.C. The importance of coal today can be inferred from the 1981 sales of coal which were on the order of 30 billion dollars and from the total value of U.S. reserves (at today's prices) of more than 160 trillion dollars. But, with its long history and high value as a resource, there is at present no established model which describes the chemical structure of coal or predicts its chemical behavior. Coal technology is presently based on empirical observations. That is, if a particular coal is to be used in a particular process, it must be tested in that process as close to full scale as possible. This is because our inadequate understanding of the chemical structure of coal and its reactivity makes it impossible to predict its behavior. Thus, we have to test each coal in each new situation in order to determine what it will do. Standard coal characterizations such as the proximate analysis (which measures a coal's volatile content under prescribed conditions) are useful in predicting the coal's behavior under similar conditions. However, proximate analysis cannot be used to predict the volatile yield for other conditions such as those encountered in pulverized coal combustion.

This lack of fundamental understanding limits our ability to design improved coal processes, develop pollution control strategies, assess the best uses for our coal resources, scale up process designs without building several intermediate size plants, or switch coals in a process without risk.

II. WHAT SHOULD BE DONE AND WHO SHOULD DO IT

History has demonstrated that sudden changes in economic and political conditions can create urgent demands for new technology. The scientific community can best meet these demands if it has command of the fundamental principles of the technology. This foundation in coal science is not presently available, and developing it is a very slow process. Such a foundation must be created in advance if it is to be available when it is needed. A program must be pursued to establish this understanding. The justification for this approach is based on my perception of several national needs: 1. To establish a secure supply of energy; 2. To reduce the outward flow of dollars for imported oil; 3. To effectively utilize the enormous U.S. supplies of coal; 4. To reduce harmful environmental effects of coal utilization. These considerations have significant impact on long term national priorities (security, economy, and environment) which require federal planning and commitment.

The task of making coal chemistry a predictive science is formidable. To make progress it is necessary to utilize fully the scientific resources in the country. This means using the ideas, scientific expertise and facilities of all appropriate disciplines from universities, industrial laboratories, national laboratories and small research companies. It also requires free dissemination of research results, freedom from the requirement for immediate product-oriented results, a long term steady commitment and cooperative programs among many laboratories.

The administration's policy is that market forces will encourage the private sector to support basic coal science and technology. This will not produce the multi-disciplined, multi-institutional, freely disseminated and sustained attack which is required. The reduction of government support would curtail the efforts at universities, national laboratories, and small research companies who are presently contributing much of the innovation in coal research. At AFR, for example, we presently spend a substantial fraction of our effort on basic research in coal and would be forced to shift to a heavier emphasis on routine analytical service work.

On the basis of short term market considerations, industry has, in the past, supported research relevant to their particular use of coal. However, basic understanding of coal and coal reaction chemistry requires substantial support for a sustained period without market constraints. The development of coal science will benefit all coal processes: combustion, liquefaction, gasification, coke-making, and production of chemicals. While no single industry can justify the total support of coal science, the integrated payoff to the nation can well justify its support.

Furthermore, there are reasons to support research in coal which do not respond to market forces, such as the security of our energy supply, the balance of payments and pollution control. Because support of basic coal science and technology are clearly in the national interest, because the program scope crosses industrial and institutional boundaries, because a goal of the program is to promote new technologies for coal utilization, the program is a legitimate and vital function of the federal government. This same conclusion was reached in the Administration's Sunset Review on the DOE.

III. WHAT HAS BEEN DONE WITH GOVERNMENT SUPPORT

Since the early 1970's, the increased federal support for fundamental coal research has resulted in progress towards providing the necessary predictive capability. Scientists from many disciplines such as physics, chemistry, biology, chemical and aerospace engineering have entered the field, bringing their specialized knowledge and their experimental and theoretical techniques. Modern techniques which are being applied in coal research include: Nuclear Magnetic Resonance (NMR), Fourier Transform Infrared Spectroscopy (FT-IR), Mass Spectroscopy, Isotopic and Other Chemical Labeling, Laser Spectroscopy, Laser Pyrolysis, New Chemical Techniques, Computer Modeling, Electron Spin Resonance, Mossbauer Spectroscopy, Gas, Liquid and Critical Solvent Chromatography, Scanning Electron Microprobe (SEM), X-ray Tomography and Computational Fluid Mechanics. For example, the Advanced Fuel Research, Inc. staff in coal research consists of two Ph.D. physicists, one Ph.D. physical organic chemist and two B.S. chemists. The scientists at Advanced Fuel Research have pioneered the use of FT-IR for coal structure characterization and on line process monitoring, SEM techniques for determining sulfur distribution and washability potential and introduced new approaches in developing a theory of coal pyrolysis. Innovative and productive research is being performed at universities, national laboratories, industrial laboratories and small research companies such as Advanced Fuel Research, Inc.

The increased effort, broadened approach, and application of modern techniques are just starting to have a real impact on coal science. The accomplishments of the multidisciplined attack on the mysteries of coal include:

- Better understanding of coal structure and its relation to physical and chemical properties, especially in liquefaction, combustion and gasification processes and in selective chemical transformations.
- Better understanding of the mechanisms and kinetics of these coal conversion processes and the role of the various components, including nitrogen, sulfur, and mineral matter as well as the basic hydrocarbon backbone of the coal.
- Better understanding of the function of catalysts in coal conversion.
- Discovery that coal is chemically reactive at low temperatures, provides the opportunity for the development of low temperature, low pressure conversion processes and for the modification of coal properties using very selective chemical reagents.

This improved understanding, in combination with the extensive characterization provided by GC, LC, MS, NMR and FT-IR, and with the application of computer codes for fluid dynamics and reaction kinetics, has led to:

- New methods for chemically transforming or modifying coal.
- New strategies for NO_x control.
- New strategies and techniques for sulfur reduction.
- Progress in correlating process behavior with coal characteristics.
- New and useful catalytic processes for commercial application.
  - Xeolite catalyst for indirect liquefaction.
  - Catalytic effect of mineral matter, especially pyrite, on direct liquefaction.
  - Use of sodium carbonate as a gasification catalyst.
- Novel physical and chemical methods for removing particulates, tar, alkaline material, sulfur, and nitrogen from raw product gas, providing more effective and economical gas cleanup for synthesis gas.

At this time, our understanding of coal structure and chemistry is gaining momentum. This growth will have substantial practical payoffs in the next five to ten years which will enable us to predict a coal's behavior and to design processes.

The Administration's proposed cuts in the fossil energy budget would devastate this effort just when results are beginning to accrue.

IV. ROLE OF THE FEDERAL GOVERNMENT

Assuming that basic coal science and technology is a legitimate function of the Federal Government, what should be the goals of the program, how should the goals be implemented, and what level of support is adequate?

The goals of the federal program in coal science and technology must be clearly defined and understood. I suggest that the goals fall quite naturally into two categories. Intermediate term goals should be to develop the understanding and techniques to properly characterize a coal and its response to various conditions and, eventually, to predict the behavior of the coal in any process. The development of this predictive capability will promote optimization of existing processes and better pollution control technology. The long range goals should focus on exploring new chemical phenomena and new analytical methods. Research in these areas will refine our understanding of the interrelation between coal structure and reactivity and will reveal new options for coal conversion and utilization.

I suggest that the program be implemented within the ADVANCED RESEARCH AND TECHNOLOGY DEVELOPMENT (AR&TD) budgets of the Department of Energy, Fossil

Energy Division since the programs presently funded under these auspices have similar goals. To assure maximum effectiveness of the program, the activities of the several branches of the AR&TD program, i.e. gasification, liquefaction and combustion should be closely coordinated and reviewed by a scientific panel of DOE and non DOE personnel to insure that the programs efficiently address the coal science and technology goals. As part of the program, a coal sample bank should be maintained and provided with a mechanism for collecting and disseminating the research results obtained on the samples from the bank.

Concerning the level of support for coal science, several studies concluded that the FY 1982 level was too low. In 1980, the Gas Research Institute sponsored a project to assess the needs in coal science. The Basic Coal Science Project Advisory Committee Report states: "The Unanimous opinion of the Basic Coal Sciences Advisory Committee is that basic research in coal technology in the United States is grossly underfunded". The National Research Council's Committee on chemical sciences has also stressed the need for substantially more support of basic energy research. To be effective, the budget must provide support for diverse approaches and promising new directions. The budget should support the best ideas from universities, national laboratories, industrial laboratories and small research companies.

The July 6, 1981 edition of Business Week reviewed typical R&D expenditures by industry. Expenditures in the fuel industry were the second lowest at 0.4%, only slightly above the tobacco industry. A composite average for all industries was 2.0%. If only 2% of the coal production was used for R&D the annual budget should be 600 million/yr.

V. CONCLUSIONS

Supporting this vital area of research can produce substantial benefits for the U.S. It can enhance our security (by insuring an adequate supply of energy), our economy (by allowing our payments for imported oil to be reduced, by promoting export of coal, and by improving coal processing technology), and our environment (by providing strategies for reducing pollution from coal). The cost of such an effort is small compared to the potential payoff. In spite of this, the Administration has recommended cuts of over 75% in the Fossil Energy budget and a 50% cut in the AR&TD budget. These cuts are well in excess of a proportionate share of the budget cutting burden and will severely curtail the long range basic research required to provide a foundation for choosing and establishing energy options.

I urge the committee to consider a responsible course of action for our energy security which will maintain the country's commitment to research. In particular, I recommend that the Fossil Energy Budget be maintained at the 1982 level and the AR&TD portion be expanded.

Peter R. Solomon, President

Advanced Fuel Research, Inc.

May 18, 1982

BIOGRAPHICAL SKETCH OF PETER R. SOLOMON, PH.D.

Dr. Peter R. Solomon received his Ph.D. in physics from Columbia University in 1965. He worked at United Technologies Research Center from August, 1965 to February 1980. During this time he was assistant to the Director of Research responsible for planning the corporate sponsored research activities and managed the coal research program. In February of 1980 he left United Technologies to form Advanced Fuel Research, Inc. of which he is currently president.

Dr. Solomon has had extensive experience in performing experimental and theoretical research in several fields including electron spin resonance, superconductivity, solid state physics and work during the last seven years in energy and coal research. He has pioneered the use of Fourier Transfrom Infrared Spectroscopy (FT-IR) as a tool for quantitative functional group determination in coal, oil shale, biomass and products derived from these materials. He also introduced the use of FT-IR as an in situ-on line detector for volatile products in coal conversion experiments and guided the development of a coal pyrolysis model. Dr. Solomon is the author of one book, over 50 publications and has had 5 patents issued.

Mr. FUQUA. Thank you, Dr. Solomon.

Dr. Sellars, coming from industry, you heard the comments made by Dr. Solomon about the legitimate function of the Federal Government being to support basic R&D in coal and that probably the private sector would not support it in that fashion.

What would be your comments on that?

Dr. SELLARS. I would agree with Dr. Solomon. I do not think that private industry is capable of stepping up to something like general coal research.

In the first place, the coal industry, as such, is pretty fragmented. Many coal operators are apparently small. They don't have the resources to do R&D strictly. And then companies like TRW, for instance, are putting a certain amount of money into coal research, but still that is strongly dependent on what the ultimate market for coal is. The ultimate market for coal is a little bit uncertain because of environmental problems; it is uncertain because of what is the price of oil going to be in the next 3 or 4 years. In general, it is a fairly long-term research project.

Nothing that we are doing is going to go on the open market in less than 3 or 4 years, and some of the things that we are looking at are more like 10 or 12 years away. This is very hard for a company to do that kind of thing.

Mr. FUQUA. Dr. Traeger, you proposed that research on the properties of coal-derived products which, due to the variations in the coal constituents and processes, leads to an investigation of an infinite universe of products and a combination of products.

How would you address that issue?

Dr. TRAEGER. I think it shifts back to the same comments that Dr. Solomon made having to do with understanding the basic chemistry of how coal comes apart. I think there is some outstanding research that is just now starting in studying the coal's surface as the coal comes apart.

So the first area should include fundamental studies on reactions of coal using dirty coal—not pure crystals and model compounds—and seeing how we can control those reactions. I would include work at low temperatures and low pressures and in super solvents and this kind of thing.

There are a number of approaches that many people could propose in that area.

Mr. FUQUA. Mr. Skeen?

Mr. SKEEN. Thank you, Mr. Chairman.

There were many interesting comments made during the presentation. I have to reflect a little bit about my own personal involvement or knowledge of this problem. It starts back in about the early 1970's, that we were talking about coal liquefaction in New Mexico. I think we were even at the point of trying to build a plant in northwestern New Mexico that didn't come to fruition because we had the usual squabbles over where the water was going to come from. We were also concerned about whether we could talk our Indian friends into allocating to us some of the water they had at that time.

It just amazes me in the development of this question on how we're going to use coal. I think we are all dedicated as a Nation, we have stated it over and over again, and we have huge energy resources represented by coal, but we never seem to come to any policy conclusion.

Am I wrong in that perception? What is our trouble in that area? I think that hinges, too, on why we have a hard time dedicating funds, because if we get over into the Congress, we start politicizing what we are going to do with the priorities and, of course, we're nonpolitical—most of the time. But I have sat through hearing after hearing and we have talked about having to have more funding for research and development.

Dr. Traeger, you also mentioned something—let me make sure I have it right. It was that further research, as such—and I'm talking about basic research now, on coal—would not really have any more impact on economic feasibility. Is this correct, or did I hear you wrong?

Dr. TRAEGER. I made that statement, but in a different context. I said evolutionary research on current processes—the SRC-1 process, the Lurgi process and the Texaco process, would have very little impact on the economics of putting up a conversion plant.

Using H-coal as an example, the reactor—which most of us want to do our jazzy work on—is 15 percent of the plant investment and about 10 percent of the operating costs. So if you do something magic and eliminate that part of the plant, you have saved 10 percent. That is within the noise of our estimates.

So evolutionary research, although useful, would not be expected to have a major impact on plant costs and will not change the economics of a liquefaction plant significantly.

Mr. SKEEN. Dr. Solomon, how do you take a product like coal that does not have any relationship in quality, in many cases, other than just basic chemistry, and how do you find a process that can universally turn this into some form of energy? How far down the line have we gone in this kind of research, and how much is there, in your estimation, left to do? Or have we done any?

Dr. SOLOMON. The problem is, in each process—combustion, liquefaction, gasification—we are often attempting to do chemistry problems without knowing what the chemical is that we're dealing with, or what its chemical reactions are.

For example, consider liquefaction. I would disagree slightly with Dr. Traeger on this topic. A lot of these processes dump coal in, dump a solvent in, and at the end they produce a primitive liquid that has to go for upgrading. We don't know whether some of that primitive liquid, which is very hard to upgrade, is a fundamental product of the coal or is it a product of the process. If we can turn some of the knobs and change some of the process conditions, if we knew what chemistry we were trying to accomplish, we might be able to make some of those products a lot easier to upgrade.

The idea is that by spending a small amount of money to understand the fundamentals of the process and what chemistry is taking place instead of looking at these things as black boxes, we can make at least minor advances in improving the efficiency of these processes and possibly major advances in new kinds of ways of processing coal.

The example in the liquefaction industry is one. In combustion, we are trying to reduce the NO_x levels in combustion. We are discovering that the way in which the coal nitrogen comes out in the very first part of the process controls how much of it is going to get oxidized. So again, we have a very practical problem which we are attacking by trying to get some fundamental understanding of the chemistry.

How far away is real predictive technology? I think we are at the point where we have a lot of the individual pieces of the puzzle. We have got some coal chemistry. We have got some computer models to do fluid mechanics. We have got some good bench scale reactors within which to test things. I think the problem now is pulling all of that stuff together, integrating it, and doing it within a real goal-oriented program in maybe 5 years.

Mr. SKEEN. Thank you.

One final question, Dr. Sellars. You spoke about the Gravimelt/BEACON processes for coal cleaning and gasification. Can you give me some idea of the amount of Federal funding involved in this work? Is there any way to separate that out?

Dr. SELLARS. In the Beacon system, we have put mostly TRW and Sohio money——

Mr. SKEEN. Corporate funds?

Dr. SELLARS. Yes, corporate funds. In the last year or two we have had some cost-sharing from the U.S. Government on a 70-30 basis, and we have talked about a total on the order of $2 million or so so far of Government funds. That's approximate. I can't remember the exact number, but it's on the order of $2 million.

Mr. SKEEN. With no Federal funding, Dr. Sellars, what would be your opinion about where these processes would be today?

Dr. SELLARS. I think they would move very slowly. The first object of the Beacon program was to produce methane from coal, as well as cogenerated energy. It turns out that there is at present a glut of methane and we have been looking for other applications.

We can also produce hydrogen. It turns out that hydrogen is in demand primarily for things like upgrading coal and upgrading heavy oil. So our partner, Sohio, has tried to bend us more in the direction of producing hydrogen.

I would say that their attitude seems to be to move very slowly in all of this and kind of let things work out. It would probably delay the program a considerable amount, and I mean by that maybe 10 years, if there were no Federal funds. Because large oil companies seem to take a very leisurely attitude toward developing new technology, which surprises me a little bit.

Mr. SKEEN. Well, I am not surprised, and I think your other statement reenforces this, that what they are looking for is something to market. If you haven't got a market for it, it is very difficult to design a research and go somewhere when you don't know where you're going to sell it.

Dr. SELLARS. They are very sensitive to the——

Mr. SKEEN. It makes a whole lot of sense. That's why companies do much better than we in Congress do sometimes.

Thank you all very much, all three of you. I enjoyed it.

Dr. TRAEGER. Thank you.

Mr. SKEEN [presiding]. Mr. Walker.

Mr. WALKER. Thank you.

What percentage of that which has been developed with Federal money in coal research has been spun off to industry at this point? Does anybody have a guess?

Dr. SELLARS. It would be hard to guess. A good bit of the work that we have done in the magnetohydrodynamics program, where we have learned, I think, some real fundamentals about the combustion of coal, we are trying to apply to some commercial gasification and commercial combustion products. We are still quite a ways off, but I think without the impetus of the MHD program, and the combustor program in particular in the MHD, we would not be in that field at all.

Mr. WALKER. I assume from the testimony here today that most of what we are doing we are trying to spin off into the commercial process at one point or another. I mean, there wouldn't be much sense in doing coal research if it wasn't going to have some commercial applicability at some point in the future. That's what coal is, an energy source for commercial purposes.

But my question is, what has been the payoff thus far for the research dollars that the Federal Government has paid? How much has actually been spun off of what has been done to this point? There has been some funding for the last 5 years, even going back 10 years. The Office of Coal Research has existed since what, 1961? I would just like to get some idea as to what we have bought thus far.

Dr. SELLARS. A good bit in our Beacon process, for instance, a good bit of the fundamental knowledge which we put together in the Beacon system, I think came out of research as described by these two gentlemen. I can't put my finger on exactly which spots, but it was that general background that we made use of from the literature and putting it together with some ideas of our own. So I think it did, in fact, bring forth the Beacon system on our part.

As I mentioned, the coal combustor and gasification work that we are doing was a direct output from the MHD program, which was sponsored by the Federal Government, and is being sponsored.

So at least in the case of TRW, most of the work that we are doing has some genesis back in the Federal research program of the preceding years.

Dr. SOLOMON. The low NO_x burners have gotten some impact from Federal spending. I think shaped catalysts for the Mobil process and catalytic gasification that Exxon is using started out with AR&TD funding. So there are lots of examples.

Mr. WALKER. Yes, and the staff here reminds me that the fluidized bed combustion also has been commercialized at this point, too, which would certainly fit in.

Well, the reason I asked the question is, we had some testimony here several weeks ago before the committee with regard to pollution abatement as much as anything else, and it dealt with coal. It indicated that most of the technologies that we brought on line commercially in that field over the last few years were things that we knew from many years before that, that we have somewhat changed the processes, we have upgraded them, we have made them better, but we really haven't developed much new in that field over technologies that were previously known to us.

That concerns me a little bit in terms of where we are putting our dollars, because it seems to me that some of that kind of improvement would have happened if we hadn't put a dime of research money in, but simply if we would have provided enforcement-driving regulations, that we could have done it with that.

That is the question here. If we pushed it with regulations, or if we pushed with some other mechanism, would industry then put the money in and save us some of the research dollars if, in fact, we are not getting really new techniques out of the money and they are not techniques which can ultimately be commercialized?

Dr. SELLARS. One of the areas, Mr. Walker, that we have been working in, too, which I forgot to mention, is coal cleaning. Our original work in coal cleaning did start with a Federal program, which I mentioned in my testimony has evolved into the Gravimelt program. Again, there we are getting Federal funding.

Now, it is possible that if you pass a law that says somebody has to use coal a certain way or can't pollute, that you could get some research out of it. You would probably not get much help from people like Dr. Solomon or Dr. Traeger or TRW because we are not in the business, in a certain sense, of using a large amount of coal. Many of the industries that are—for instance, the utilities—are in pretty bad shape financially and are not able to put large amounts of money into developing new processes.

On the other hand, they are being regulated pretty heavily and I think to a certain extent they should be. It seems to me that what you would do is overlook a whole segment of the population that could make some contribution and put the burden on people who are probably not too well equipped to do it in many cases.

Dr. TRAEGER. If I could just take a stab at that, there are two things: One, there is a whole series of small items, like diagnostics and instrumentation, better pumps and valves, and slurry handling and materials that have been developed in the coal programs and now are being used throughout the refineries and other places. I don't know how to quantify this, they are going on.

Coal cleaning I think is a very valid one. There was a recent international meeting on coal cleaning, and some of the 15 new concepts for coal cleaning were proposed by scientists from the United States. They are being tried internationally. How much is spun off right now, I can't say.

Currently in the coal gasification area there are a couple of small plants. Eastman is putting up a plant to make acidic an hydride using coal gasification. Grace is looking at a small one for methanol. And there is Coolwater, a gasification plant that is being put up by EPRI and a consortium. Most of that groundwork was done under the DOE programs.

Again, quantitatively, how much is transferred? I can't answer that question.

Mr. WALKER. Well, the reason why the question comes up, in all honesty, is because in the discussions in this committee we end up having the argument made time and time again that the payoff is huge, you know, that you just spend this money and you will get more money back than you are spending and all of that. One of the things I would like to find out from some of the witnesses who come before us how much have we gotten back. If we have spent $100 million over 5 years in coal research, can we show how much new investment is out there, how much we have gotten back from that spending in terms of what can be used commercially and what is now in the marketplace. Those are really the kinds of figures that I am looking for.

Dr. SOLOMON. I can't give you those figures, but I think it points to a real problem. As an example, consider sulfur. A lot of work has been done in sulfur cleaning, but that work has gone on in the absence of information on what the forms of sulfur are in coal, the different organic forms that you have to clean.

The goal of the program has not been to get us to the point where we have a fundamental base on which to build these technologies. It has been goal-oriented:

> I want a process to clean sulfur. If you have a good idea to clean sulfur, I'll fund that. But I am not going to fund a program to identify the different chemical forms of sulfur in coal.

And if you're going to do chemistry to remove organic sulfur, you have got to know what those forms are. Otherwise, you are operating in the dark. You are doing recipes. That is a very difficult way to make progress.

I think an interesting result has come out of a lot of that work, and that is that every single oxidative process to remove sulfur from coal removes more Btus than it does sulfur, so the sulfur per Btu content continues to go down as you use the process.

Mr. WALKER. I think you make an excellent point, and I think it is one of the things that we sometimes fail to consider in this committee, as to just exactly where our research dollars ought to be going and where there are other ways of accomplishing the same things in terms of research with other kinds of mechanisms of the Federal Government.

I would agree with you. I think the kind of thing you are talking about is where the research dollars should be going. I think there are some things happening within coal and a lot of other energy sources where I find it very hard to justify the fact that we're spending Federal research dollars on it, because I am not certain we are getting real research out of it. I am convinced that what we are getting in many cases is buys of products that would otherwise be available, but are taking the easy route of coming up with Federal money. I think you make an excellent point and I think it is one of those things where we have got to be awfully careful about what we identify as research and the kinds of things where there is basic knowledge being gained that then spreads across the whole board. That is where I think we ought to be spending our research dollars.

Dr. SOLOMON. But we cannot simply leave it to organizations like the National Science Foundation, which has a broad goal of supporting fundamentals. What we need are fundamentals which are aimed at a benefit, and that is a foundation of understanding of coal chemistry so we can build processes on it.

I think we do want to have the goal of utilizing this information for process development, so in that sense it is a very focused program of fundamental understanding.

Mr. WALKER. Thank you, Mr. Chairman.

Mr. FUQUA [presiding]. Thank you, Mr. Walker.

Mr. NELSON. Do we have any technical or scientific manpower problems in any of these areas of coal research?

Dr. TRAEGER. From my viewpoint with the past DOE contributions and interest, there are a lot of converted physicists who got out of solid state because that money field dried up—excuse me, Peter—and a lot of chemists and other people are now very heavily involved in coal chemistry and in coal engineering. If you go to the Exxons, the Mobils, and the Gulfs, they have a number of people who are excellent engineers. So I think right now we're in good shape.

However, looking at the future, the scientists in the universities are getting out of coal research just because they see the funds drying up; they are looking for other areas. Similarly, my crew is getting out of the business just because our funds are drying up.

If, indeed, the proposed funding cuts go through, in 3 or 4 years we could be back to the stage that we were 20 years ago when we had a few people doing some limited coal research. The staff would be inadequate should you really need a buildup in the case of an emergency.

Mr. NELSON. Do you all concur?

Dr. SELLARS. I think that's a very good summary.

Mr. NELSON. What are the appropriate roles for universities, industry, and the national laboratories in advanced coal research?

Dr. SOLOMON. I responded to that in my testimony because I understood it was an important question for the committee.

I think that we are interested in a goal of understanding. We ought to be funding the best ideas, the best proposals, the places that have the facilities to do the job, without any prior prejudice on who ought to be doing the work.

In terms of funding universities, there is an additional function of educating graduate students so that we have the professional skills available. So that ought to be considered as another need for the university funding.

But for basic research funding in coal science, I think we just fund the best ideas and I think we have to get the input from all of these different organizations to help DOE in directing the coal research at the fundamental understandings.

Dr. **Traeger**. I would like to just comment in general.

The national labs and NASA have historically worked on overall systems. They do a systems analysis, identify the key questions, and then attack them, whether it is physics or chemistry or engineering or whatever. The R&D is done outside or inside, whoever has the expertise.

Universities are discipline oriented, so they attack problems in their discipline. It is hard to get chemists to talk to other chemists, much less chemists to talk to physicists in universities. They admit that.

So if, indeed, you had a goal oriented program, which I think you need, the university is not the place to manage it. The university will have expertise that can do much of the research. Now, who focuses the program? Industry is good at focusing programs. They have to to make profits. The national labs, in the weapons area particularly, have focused programs. NASA runs focused programs. Energy technology centers just lately, in the latest crisis, have started to develop the capability of running focused programs.

Dr. **Sellars**. It seems to me that the function of industry ultimately is to find a product to sell. We go into basic research to the extent necessary to uncover these products and develop them, not for its own sake, as a rule. Now, in some cases we end up spending quite a lot of money and time in what I would call fairly basic research. In fact, we discover quite a bit of basic data in doing so. But in the end, our object is to find something that is profitable, when you look at the amount of money we have to put into it, the time involved, and ultimately what the market is.

Mr. **Fuqua**. Thank you, Mr. Nelson.

I want to thank our panel for being here and sharing with us your views. Thank you very much.

Our next panel of witnesses will be my good friend, Dr. Alex Green, a graduate research professor of physics at the University of Florida. He will be followed by Dr. Michael Jefferies, the manager of research and development for the General Electric Co., and Dr. Charles E. Kolb, vice president of the applied science division of Aerodyne Research, Inc.

Alex, we are very pleased to have you here today. You may proceed with your statement.

STATEMENTS OF DR. ALEX E. S. GREEN, GRADUATE RESEARCH PROFESSOR OF PHYSICS, UNIVERSITY OF FLORIDA, GAINSVILLE; DR. MICHAEL J. JEFFERIES, RESEARCH AND DEVELOPMENT MANAGER, ENERGY SCIENCE AND ENGINEERING, CORPORATE RESEARCH AND DEVELOPMENT, GENERAL ELECTRIC CO.; AND DR. CHARLES E. KOLB, VICE PRESIDENT, APPLIED SCIENCE DIVISION, AERODYNE RESEARCH, INC.

Dr. **Green**. Mr. Chairman, I appreciate the opportunity to testify before this committee.

My involvement in coal research needs has come about through some recent studies which an interdiciplinary group of professors on the University of Florida campus have put together, which suggest that the usefulness of coal resources of this country could be greatly increased in the immediate future by retrofitting existing oil boilers to simultaneously burn coal or coal-water slurries with natural gas. It is a rather simple idea that perhaps was just overlooked because the Fuel Use Act of 1978 was telling the country to get out of using oil and natural gas, in utility boilers and in industry.

In effect, in this process, oil was synthesized from coal with the help of a small proportion of the natural gas in the very process of using it. Since early 1981, I have been a scientist and the director of an interdiciplinary group with an idea which we think has merits, looking for research funds to develop this idea.

Unfortunately, while almost everybody recognizes that our coal resources are our major fallback position for the next few decades, there is very little or no research funds directed toward applied research on gas-coal fuel blends. Under the reduced budgets that this field has labored under, the prospects for supporting this or any other promising new direction that hasn't been identified in existing programs is very limited.

In consequence, I strongly recommend that the fossil fuel energy research budget of the Federal Government be very substantially increased, particularly to encourage scientists and engineers from many disciplines to make contributions to coal research.

Let me describe the studies that this position is based upon. In 1979, we responded to a State's request for study on the possible impact of increased coal use in Florida. Florida is unusual in that 59 percent of its electric generation is based upon oil, whereas the national average is about 15 percent oil base. Thus Florida is particularly vulnerable to increases in the price of oil.

We carried out this study and reported our general results in a book, "Coal Burning Issues," with contributions by about 30 professors. We thus managed at the university to cooperate across interdiciplinary lines rather effectively. We brought out this book in record time, a book which looked at coal burning issues from a national perspective.

We also carried out a State study on the particular problems of Florida. Both studies the State and the Federal study concluded that the Nation, and particularly the State of Florida, must quickly reduce its excessive reliance upon foreign oil. We concluded that conservation measures and the increased reliance on the national coal supply were the major alternatives available to us in the next two decades.

At the conclusion of these two studies in December 1979, we heard reports that there is more gas around than people had previously thought. We looked into this question rather thoroughly and came to a conclusion that we should broaden our options to include the use of our natural gas reserves, at least for the next two decades or so, to foster the clean burning of coal and the displacement of oil. This seemed like a reasonable idea and in the year and a-half I have pursued this idea, I have heard no challenge of the technical merits of this idea.

We then carried out an economic analysis as to what the use of this blend would buy us as a way of retrofitting oil boilers to burn coal. If we burn coal in existing oil boilers these boilers would usually have to be derated quite substantially. But by adding a little bit of gas—I'm talking like 30 percent gas energy and 70 percent coal energy—we can minimize this derating in most cases.

We carried out an economic analysis of this last summer and came to the conclusion that in the State of Florida alone we could save $2.5 billion a year in energy costs by using this fuel blend as compared to staying with residual oil. We had not expected the economic benefits to come out this big.

We compared this particular retrofitting philosophy to the coal-oil -mixture philosophy, which has been given quite a bit of national attention and funding. We also considered the notion of retrofitting the oil boiler for dual coal or oil use and to the option of building a new coal-fired boiler to provide steam for the existing electric plant, and also what is currently a major approach which is to use a coal water slurry. Thus in our study we compared this gas-coal concept or gas-coal-water concept with concepts that were already under study. We found that the savings by the gas-coal or gas-coal-water concept could easily compete, certainly with the coal-oil mixture concept, and with the other approaches as well.

The biggest thing that influenced our price projections was the price difference between oil energy and coal energy. Gas energy is not so important because we are only using about 30 percent gas energy and we are using gas primarily to facilitate the burning of coal in the existing oil boiler.

Well, as a result of this analysis, which suggests great savings are possible, we did a national estimation and we found that nationally in utilities alone we could save about $12.5 billion a year by converting oil boilers to gas and coal. If we utilized this idea for industry, we could save another 2 million barrels of oil a day. Perhaps another million barrels of oil a day could be saved in the commercial and residential use of oil. These savings would bring the United States to the point of a normal balance of payments with the OPEC nations.

I must emphasize that to execute this type of retrofitting nationally would not require vast new supplies of gas. We would only need about two trillion cubic feet a year of natural gas to help us phase out of 3 million barrels a day of oil—that's about 10 percent of our current natural gas production. On the other hand, it would take about 25 percent of our current coal production to provide the remainder of the displaced oil energy. Thus this gas-coal-oil displacement concept relies much more on coal energy than gas energy.

Well, this idea is gaining some attention, and there will be a national conference on it in the fall with participation by major industrial firms including Babcock and Wilcox, Combustion Engineering and Batelle. Nevertheless, in straying into this field, I found a lack of openness to new directions and new ideas, which I think should be considered in the hearings of this committee.

Let me conclude with some personal observations. I was a graduate student at CalTech when the Japanese struck at Pearl Harbor on December 7, 1941, and I can say that within 2 or 3 months a good fraction of the faculty members and graduate students at Cal-Tech, including myself, were participating in all types of defense research. It wasn't that you had to be a card-carrying rocket engineer to develop rockets. Nuclear physicists were right up there at JPL developing rockets. The whole scientific community made a tremendous variety of contributions to the winning of World War II.

I made my first proposal, an idea for scoring anti-aircraft gunners firing on target rockets which was funded very quickly. The initial idea was to use magnetic bullets and a detector with radio transmitter in the target. However, soon after we got going it evolved into other types of devices which were useful during the war effort. During the last year of the war this background led to serve an operations analyst with the B–29's in the strategic bombardment campaign against Japan. During this period I don't remember any reasonable idea which might help get the job done not being given the opportunity to be tested. As you remember, we did get the job done.

Now, since World War II, I have been actively involved in many research projects. I have wandered into more topical areas than most physicists and I had funding from almost all the major national R&D funding agencies—NASA, NSF, DOE, Air Force, Navy, and so forth. During recent times I have noted in our R&D an increasing tendency to parochialism, balkanization, territoriality, shortsightedness, and the so-called NIH syndrome, not invented here. The notion that one person invents something and then passes it on to someone else to develop rarely works and it works less today than it worked in previous times.

I think Bill Patterson of GE will remember our days together about 20 years ago at Convair, General Dynamics, when I was chief of physics there for a few years. We had a concept of the physicists getting the ideas, and turning them over to the engineers to develop. But the factor that usually defeated us was this NIH syndrome, not invented here.

Well somehow we have to overcome this, and I think just more money won't do it. We certainly need more money for fossil fuels research, but in addition to more money, we somehow have to broaden the participation of scientists and engineers working on fossil fuel problems. These problems command the greatest attention of this country now because no matter how much we want to shift to nuclear energy or solar energy or other unconventional forms of energy, we will be generating most of our energy in the next few decades with fossil fuels, particularly coal.

I agree with some of the earlier speakers, that we need to achieve a broad range of understanding of what we are doing to bring concepts into the development phase.

Well, let me conclude by saying I sincerely believe the United States could achieve energy independence within 4 or 5 years, if we recognize that we, in effect, are now engaged in an economic war of survival analogous to the fighting war of World War II. We, however, need a willingness to place a high national priorty on the goal of energy independence and balance of trade. We have an abundance of coal and we also have an adequate reserve of natural gas to help burn coal cleanly and to displace imported oil. What we need now is the will and leadership to get the job done.

Thank you.

[The statement of Dr. Green follows:]

Statement of Alex E. S. Green
on
Coal Research Needs
to
Subcommittee on Energy Development and Applications
Committee on Science and Technology
U.S. House of Representatives
May 18, 1982

Abstract

Several recent studies indicate that the usefulness of the coal resources of the United States could be substantially increased by retrofitting existing oil boilers to simultaneously burn coal or coal water slurries with natural gas. In effect, oil is synthesized from coal with the help of a small proportion of natural gas in the very process of its use. Unfortunately little or no research funds have been directed toward applied research or development work on these fuel blends. Under reduced budgets the prospects for support for this and other promising new directions are very limited. It is strongly recommended that the fossil fuel energy research budget of the U.S. Department of Energy be substantially increased, particularly to encourage scientists and engineers from many disciplines to make contributions to coal research.

Biographical Sketch

A. E. S. Green is a graduate research professor of physics and nuclear engineering sciences at the University of Floirda, Gainesville. He is the director fo the University's Interdisciplinary Center for Aeronomy and (other) Atmospheric Sciences (ICAAS). As a graduate research professor he has affiliations with the departments of engineering sciences, electrical engineering, astronomy, chemistry and mechanical engineering. In his current and prior capacities he has made contributions to radiation, atmospheric, atomic, nuclear, and particle physics and operations analysis.

Dr. Green is the editor of "Coal Burning Issues" which reports the scoping phase of an interdisciplinary assessment of the impact of increased use of coal (1980). He is also editor of "An Alternative to Oil: Burning Coal with Gas" (1982), which describes the economic and environmental benefits of burning coal with natural gas mixtures in boilers originally designed for oil. This written statement is largely a summary of this latter monograph. It includes Chapter 11 which describes research and development needs for implementing the gas-coal approach.

1.1 Introduction and Overview

The Interdisciplinary Center for Aeronomy and (other) Atmospheric Sciences at the University of Florida has recently completed several broad studies on coal burning which suggest necessary lines of research. The first, "Coal Burning Issues" (ICAAS, 1980a) a monograph written in a national context reported the results of the scoping phase of an interdisciplinary assessment of the impact of the increased use of coal. The second study, a report entitled "The Impact of Increased Coal Use on Florida (ICAAS, 1980b) (IICUF)", attempted to determine major economic, social, environmental and technological issues to be considered in reference to increased coal burning in Florida and to project the options available to the state attendant to each issue. The major conclusion of both studies was that the nation and particularly the State of Florida must quickly reduce its large reliance on foreign oil and that conservation measures and increased reliance on the abundant national supply of coal were the major alternatives available to us in the next few decades.

The third study "Gas-Coal Burning Options" (Green and Jones 1981) considered increased estimates of our natural gas reserves and concluded that the United States and the State of Florida should broaden its transitional energy options to include the development and utilization of simultaneous gas-coal burning combinations for industrial and utility boilers. The complementarity of this study with economic analyses favoring the select gas use with coal under the bubble concept (Schlesinger 1980, AGA, 1981) led to a grant by the American Gas Association to study economic aspects of converting Florida's electric utility oil boilers to the simultaneous burning of coal with gas.

This fourth study (Green et al. 1981) accepted recent analyses which indicated that natural gas production levels in the United States are sustainable to the year 2000 at the 20 trillion cubic feet (TCF) level. Thus natural gas need not be phased out of utility and industrial applications as originally specified by the 1978 Power Plant and Industrial Fuel Use Act. The study evaluated the simultaneous use of gas with coal to replace residual oil in Florida utility steam boilers originally designed for oil burning. The conversion costs (in $/kilowatt) were estimated for various oil-backout options: (a) coal-oil mixtures, (b) dual coal or oil use, (c) new coal-fired boiler, (d) gas-coal, (e) water-coal, and (f) gas-coal-water. Simplified economic comparisons based upon the annual costs of a 200-megawatt unit favor the gas-coal option. A more refined and detailed economic analysis of the conversion to gas-coal of 12,678 megawatts of suitable oil boiler capacity in Florida which allowed for fuel and general inflation rates and economies of scale indicated a savings of 2.5 billion dollars per year in annualized electric generation cost. This savings was in 1980 dollars, over the 1980-1995 period and corresponded to a reduction of about 50 percent in the annualized power production cost.

The most important factor that influenced our economic projections was the price difference between oil and coal energy. Gas energy on the average plays only a 30 percent role. The air quality impact of conversion from oil to gas-coal was also examined and it was shown to be possible to maintain or improve upon current emission standards.

The special nature of Florida's problem is illustrated by Figure 1.1, which gives the 1980 United States Energy Consumption and Figure 1.2, which projects the 1980 Florida Energy Consumption. Thus Florida represents an extreme example of excessive reliance upon oil in electrical generation, a problem of the USA as a whole.

The striking economic benefits of burning ~~oil~~ coal with gas indicated by our Florida study motivated us to broaden the work into a monograph "An Alternative to Oil: Burning Coal with Gas" (Green et al. 1982). This fifth study projected from the Florida study a national savings of 12.5 billion dollars per year in utility costs, corresponding to a saving of 1 million barrels of oil per day. Another 2 million barrels per day could be saved in the industrial use of oil and possibly an additional 1 million barrels per day in the commercial and residential use of oil. The savings would be equivalent to a saving of about 50 billion dollars per year in energy costs. The title, contributors, table of contents and publisher of this monograph follow.

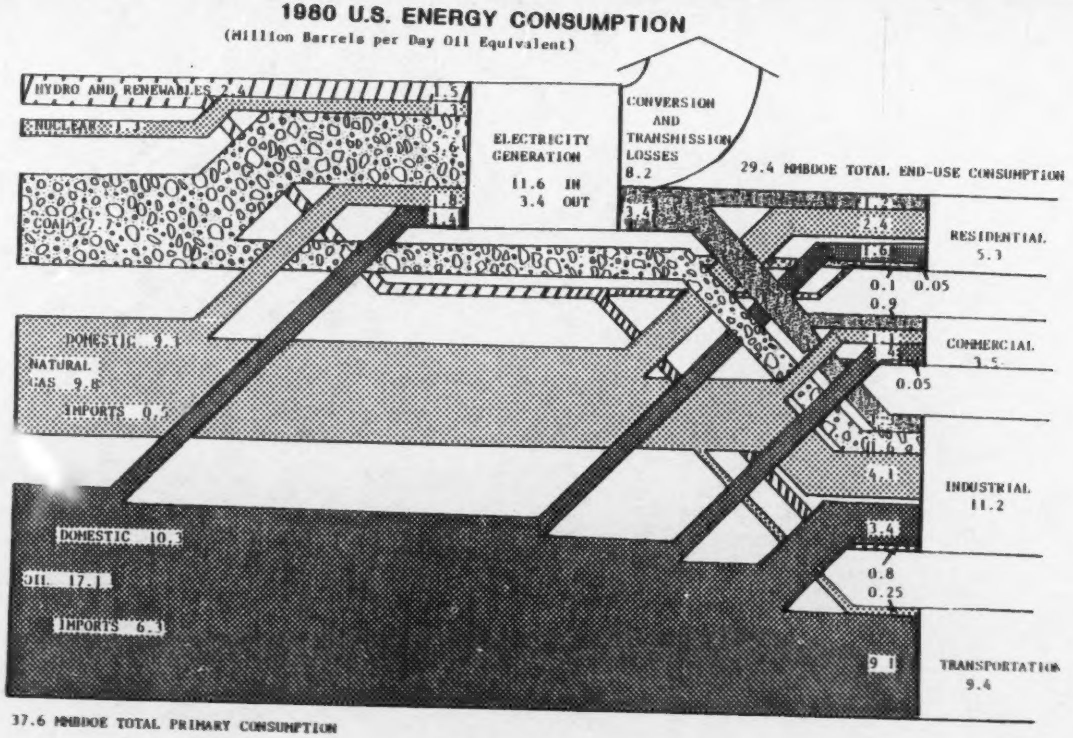
1980 U.S. ENERGY CONSUMPTION
(Million Barrels per Day Oil Equivalent)
HYDRO AND RENEWABLES 2.4
NUCLEAR 1.3
COAL 7.7
1.5
1.3
5.6
1.8
1.4
ELECTRICITY GENERATION
11.6 IN
3.4 OUT
CONVERSION AND TRANSMISSION LOSSES
8.2
3.4
29.4 MMBDOE TOTAL END-USE CONSUMPTION
1.2
2.4
1.6
RESIDENTIAL
5.3
0.1
0.05
0.9
1.1
COMMERCIAL
3.5
0.05
1.6
4.1
INDUSTRIAL
11.2
3.4
0.8
0.25
9.1
TRANSPORTATION
9.4
DOMESTIC 9.1
NATURAL GAS 9.8
IMPORTS 0.7
DOMESTIC 10.3
OIL 17.1
IMPORTS 6.3
37.6 MMBDOE TOTAL PRIMARY CONSUMPTION

Fig. 1.1 United States Energy Supply and Disposition for 1980 (from Department of Energy 1980 Annual Report to Congress DOE/EIA-0173 (80)).

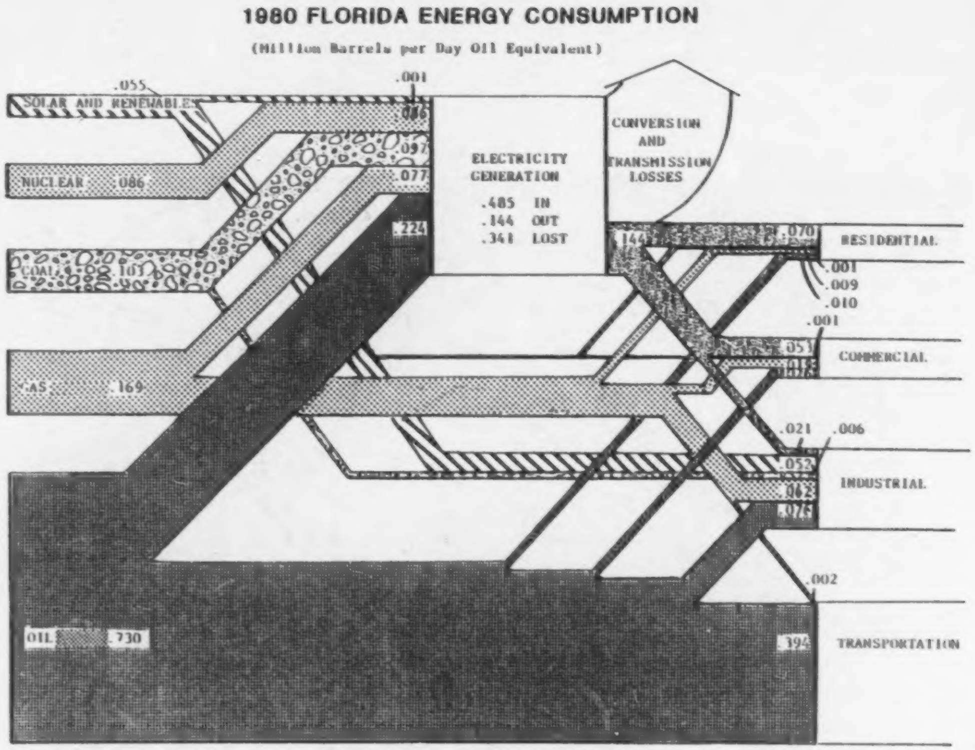
1980 FLORIDA ENERGY CONSUMPTION
(Million Barrels per Day Oil Equivalent)
.055
SOLAR AND RENEWABLE
.001
.086
.097
.077
.224
NUCLEAR .086
COAL .103
GAS .169
OIL .730
ELECTRICITY GENERATION
.485 IN
.144 OUT
.341 LOST
CONVERSION AND TRANSMISSION LOSSES
.144
.070
RESIDENTIAL
.001
.009
.010
.001
.051
COMMERCIAL
.021
.006
.052
.062
INDUSTRIAL
.002
.394
TRANSPORTATION

Figure 1.2

Fig. 1.2 Florida's Energy Supply and Disposition for 1980 (data from Forecasts of Energy Consumption in Florida 1980-2000, Sept. 1981, State of Florida Governor's Energy Office).

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AN ALTERNATIVE TO OIL: BURNING COAL WITH GAS

The economic and environmental benefits of burning coal and natural gas mixtures in boilers originally designed for oil

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Section 1.2 Summary of Gas-Coal Burning Monograph.

The gas-coal burning effort began in January of 1981 shortly after the completion of two interdisciplinary assessments, Coal Burning Issues and Impact of Increased Coal Burning on Florida (ICAAS 1980a,b). It was motivated by a strong concern that we had overlooked the possibility that natural gas production rates could be sustained at a level of 20 TCF for the next two decades or so. As we looked into this question (Green and Jones, 1981), we became convinced that this possibility was appreciable. In February of 1981 we initiated a small development program and in March a scientific program. In June, we initiated an economic analyses of oil boiler conversion in Florida which was completed in August. The economic benefits indicated in the third endeavor (see Chapters 5-8 of this monograph) were far beyond our expectations and together with knowledge gained during the development and scientific programs these projected benefits convinced us that the gas-coal approach could and should openly stand as a contender with the coal-oil mixture, dual coal/oil, a new coal boiler and coal-water mixtures approaches to oil boiler retrofitting. The pay-off for the United States from oil boiler retrofitting is very large and the displacement of 4 or so million barrels of oil per day seems quite feasible. This level of reduction would bring the United States within the range of a normal trade balance with the OPEC nations.

We must acknowledge that there are unusual obstacles to the implementation of the gas-coal approach. In the first place the Power Plant and Industrial Fual Use Act of 1978, which assumed that gas production rates would decline precipitously by the year 2000, provides legal obstacles despite the fact that it is now being interpreted with very great flexibility. In the second place none of the agencies which would naturally support oil-backout research and development endeavors such as the Department of Energy, the Environmental Protection Agency, the Electric Power Research Institute, the Gas Research Institute or the National Coal Association has a preexisting program to pursue the gas-coal option. In days of very tight R and D budgets it is difficult to establish a new program. In the third place, to implement the gas-coal approach would require an unusual degree of cooperation by diverse groups including the electric utility industry, the boiler manufacturers, the gas and coal producing and distributing industries, and the federal and state regulatory agencies that are concerned with energy-environmental problems.

Despite these serious obstacles, we believe, after 18 months of intensive involvement with scientific, technological, economic and environmental aspects of burning coal with gas, that the approach warrants serious consideration by the United States. Not only does it offer great promise as a way of backing out of using oil in existing boilers and furnaces but it also suggests a simple design path for developing improved systems for burning a variety of solid fuels simultaneously with natural gas.

From a broad perspective we are basically close to where ICAAS was following its CBI and IICUF studies (ICAAS 1980a, b). To deal with our excessive oil imports problem we advocated strong conservation measures and increased reliance upon our nation's abundant supply of coal. However, among the ways of utilizing coal as an alternative to oil, we believe now that burning coal with gas is environmentally cleaner than coal alone. Furthermore it can permit coal use in boilers originally designed to burn oil without substantial derating.

In final conclusion we might note that during World War II this nation in a short span of time brought forth many new high technology developments - radar, pressurized high altitude aircraft, solid fuel rockets, and the release of nuclear energy, to name but a few examples. The technology to implement the displacement of oil by burning coal with gas does not compare in complexity with these wartime developments. However, since World War II we appear to have lost considerable economic strength and common purpose. Somehow, when addressing important national problems we must again set aside territorial imperatives, and political mistrust and work together towards the common good. Clearly we must strive towards a balance of trade which does not require that we sell our land and resources (i.e. our future) to make up for our immediate demands for foreign products, particularly oil.

1.3 State of the Gas-Coal Burning Literature

About the same time as the initiation of the Green-Jones (1981) study, an experimental study of natural gas-pulverized coal burning was started using a burner in the 0.5 million BTU/hr range. This field program was influenced by two years of exploratory thinking and discussion (Green and Green 1980, 1981) on the use of coal to displace propane burning by a production pottery kiln. Shortly thereafter a laboratory study of gas-coal flames was initiated using a burner in the 10,000 BTU/hr range (Horvath, Vaidya and Green 1981). The primary intent here was to carry out gas-coal burning under carefully controlled conditions and to use the observations to help develop a theoretical model of this mixed combustion process. Most of the observations were carried out with the use of middle ultraviolet spectroscopy since refined instruments were available to utilize this specialty of the editor (Green 1966, 1981). The radiations emitted by various zones of gas-coal flames are being used to obtain information about the chemical, radiative and flow processes taking place in heterogeneous gas-coal flames.

These experimental and theoretical efforts, collateral to the AGA-ICAAS economic study, led to a rapid familiarization with the literatures of pulverized coal combustion and natural gas combustion, two vast technical and scientific literatures. This familiarization revealed a paucity of flame studies of natural gas-pulverized coal mixtures, apparently accounted for by the absence of applications for this fuel combination. While combustion studies have increased substantially in the United States in recent years, most of the new studies have been directed at answering the question of whether we can use our abundant supply of coal to develop alternative fuels to substitute for oil and natural gas? Attempts to answer this question largely derive from the 1978 Power Plant and Industrial Fuel Use Act (PIFUA), which reflected the national concern that the oil and natural gas reserves of the USA were depleting rapidly. The possibility that domestic natural gas supplies are not at great risk for the next 20 years or so has been raised only very recently. If one grants this possibility, then different questions arise: How can we use our abundant reserves of coal and our modest supplies of natural gas to displace oil so as to minimize our imports, a major source of our current economic problems? While addressing this economic question, how can we use natural gas to mitigate the environmental consequences of increased coal burning? This monograph addresses these questions.

1.4 Coal and Natural Gas Supplies

It is generally recognized that the United States is well endowed with coal reserves and that it has coal production capabilities considerably in excess of current coal production levels. The gas supply situation is, however, the subject of some controversy with substantial differences appearing in estimates by authoritative groups. Figure 1.3 shows the projections of the Tennessee Gas Transmission Co. (TGT) 1981, a more conservative view of our production capabilities through the year 2000. The various shaded areas from the bottom upward designate production from (A) proven reserves established by 1980 in the "Lower 48" (B) future reserve additions in the Lower 48 (C) offshore Atlantic reserves (D) Alaskan reserves excluding liquefied natural gas (E) conventional pipeline imports from Canada and Mexico.

The curve immediately above the shaded area represent TGT's total production estimate. This includes all nonconventional sources of natural gas (R) such as liquefied natural gas from other foreign countries, synthetic natural gas from coal, and the sum of other new technologies or sources.

The upper lines with arrows on Fig. 1.3 gives the 1981 estimates of the American Gas Association under the assumption of a scenario which emphasizes North American supply sources and considers a broader range of nonconventional sources. The higher points of the range imply two major assumptions. "First, that there is a vigorous national R&D effort to improve the technologies related to gas production and, second, that federal policy and regulatory decisions support, consistent with the scenario description, increasing gas supplies. The low estimate points are based on an indifferent national R&D program with dilatory federal and regulatory policy decisions," (Wilkinson 1981). Both AGA and TGT estimates indicate that gas supplies to the year 2000 will be available at the 20 TCF/yr level, a level also accepted in the most recent National Energy Plan.

This 20 TCF level of gas supply gas considerable significance from the viewpoint of the gas-coal-oil displacement thesis. Table 1.1 summarizes the gas and coal supplies per year needed to displace various levels of oil use. Our current annual coal production is at a rate of about 700 million tons per year and our production capability is about 800 million tons. From the entries in the table it should be obvious that even a displacement of 3-5 million barrels of oil per day could readily be accommodated with only minor or modest increases in our domestic gas and coal production capabilities. With some redistribution of our current gas uses it should be possible to accommodate even greater levels of oil displacement. Accordingly the gas-coal-oil displacement approach can be accommodated from a supply standpoint.

1.5 A Summary of the Physical Basis of Gas-Coal Replacement of Oil

Chapter 4, The Physical Basis of Gas-Coal Replacement of Oil, discusses various physical reasons in support of the concept that gas and coal can displace oil in utility boilers. These reasons rest largely upon the intermediate nature of various properties of residual oil as compared to gas and coal. Figure 1.4 (adapted from Ehrlich, Drenker and Manfred 1980) illustrates this intermediate character of oil with a display of the relative sizes and boiler design differences for coal (bituminous), oil (residual) and gas (natural) boilers which produce equal steam power output. Other examples of such properties are summarized in Table 1.2. Because of the intermediate characteristics, it is reasonable to expect in all matters with the exception of ash problems that a gas-coal mixture fed into the burning zone of an oil boiler would burn somewhat like oil. Ash problems such as slagging, fouling, increased corrosion, tube erosion, plugging of air passes and increased particulate emission require more complex measures (Babcock and Wilcox 1978, Combustion Engineering 1981). The particulate emissions problem can be handled by the use of highly efficient precipitators or bag houses. Means of dealing with the other expected ash problems are just being developed as various approaches to oil boiler retrofitting are now being examined, tested or carried out. These approaches include (1) conversion to coal oil mixtures such as recently undertaken at the Sanford Station in Florida (Cook 1980),

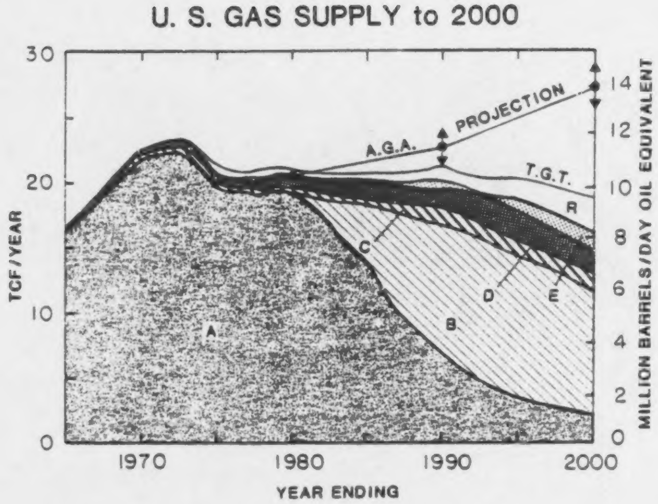

Fig. 1.3 U.S. Gas Supply Projections to 2000 (Adapted from p.18, Energy 1901-2000, the Tennessee Gas Transmission Company, Houston, Texas, August 1981). The upper straight line segments represent the American Gas Association estimates under a scenario which emphasizes North American supply sources. The arrows indicate the range of estimates.

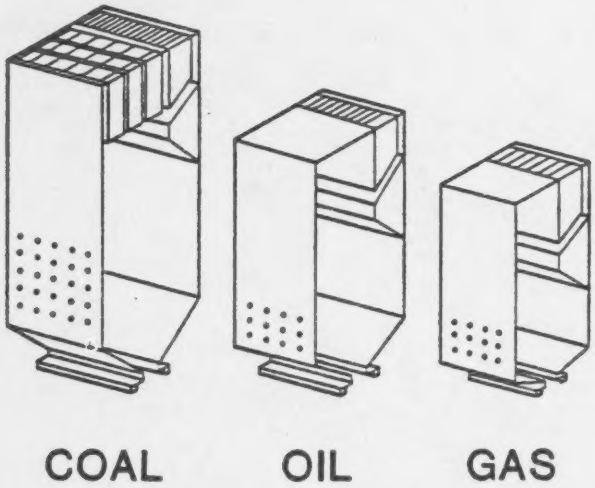

Fig. 1.4 Relative Sizes and Features of Coal, Oil and Gas Boilers (from Erhlich, S., S. Drenker and R. Manfred, Coal Use in Boilers Designed for Oil and Gas Firing, American Power Conference, Chicago, Illinois, April 21-23, 1980.

Table 1.1 Gas and Coal needs for various oil displacements
(using a 30/70 by energy gas/coal ratio)

Oil Displaced		Gas Required		Coal Required	
μ	Quads per yr	TCF per yr	% Nat. Prod. (20 TCF)	Million Tons per yr	% Nat. Prod. (800 10^6T/yr)
1	2.2	0.66	3.3	64	8.0
2	4.4	1.31	6.6	128	16.0
3	6.6	1.97	9.8	192	24.0
5	11.0	3.28	16.4	319	39.9
7	15.3	4.60	23.0	447	55.9

μ = million barrels of oil per day ≈ 2.2 quad per yr
TCF = trillion cubic feet ≈ 1 quad
Quad = 10^{15} BTU ≈ 41.7 million tons of coal

Table 1.2 Characteristics of Gas, Oil and Coal

	Gas	Oil	Coal
Relative power density	1.6	1.0	0.73
Calorific value (10^3 BTU/lbs)	24	18	12
Air/fuel ratio by weight	20:1	17:1	11:1
Hydrogen/Carbon by weight	1.3	1.9	1.20
by atom	4	1.6	0.8
SO_2 emission (lbs/10^6 BTU)	0	0.5 - 3	1 - 6
CO_2:H_2O emissions	0.5:1	1.2:1	2.5:1
Burning time	fast	intermediate	slow
Radiation	low	middle	high
State of matter	gas	liquid	solid
Ash levels (percent)	0	0.2 - 0.5	1 - 10

(2) conversion to coal use with the maintenance of oil firing capability as recently carried out at the Kwinana power station in Perth, Australia (Kirkwood et al. 1978), (3) the installation of a new coal boiler to be used with the remainder of the electric plant (Philipp 1979, 1980, Ehrlich, Drenker and Manfred 1980) and (4) the use of coal-water slurries (ibid., Glenn 1979). In addition various types of clean fuels derived from coal using hydroliquefaction processes or chemical coal cleaning or coal gasification have been proposed, but for the most part these will not be available until the 1990s.

No prior literature appears to exist on the use of gas and coal for oil boiler retrofitting, and it is hoped that this monograph will help fill this void. The measures being used for coping with ash handling problems for the first four options described above would also be applicable. In addition there is the possibility of using a first stage gas-coal combustion chamber, which separates out a large portion of the ash before the hot fuel-rich combustion gases including coal volatiles, CO, and other gases are injected into the boiler for afterburning with natural gas enhancement and secondary and tertiary air.

1.6 Economic Analyses

Chapter 5, Conversion Costs of Oil Back-Out Options, first classifies all of Florida's utility oil boilers as to their suitability for coal conversion. These classes are

A: Oil boilers located where existing or projected coal units are available.

B: Oil boilers in service approximately 25 years or less with large enough land area or port facilities to accommodate coal and ash handling.

C: Oil boilers in service approximately 25 years or less on small sites with no port facilities.

D: All remaining steam turbine oil boilers that have been in service more than 25 years.

E: All gas turbines which use distillate oil.

Classes D and E were not considered for conversion.

A methodology and simple economic analysis developed on retrofitting oil boilers to (a) coal-oil mixtures, (b) dual oil and coal capability with no flue gas desulfurization (FGD) and (c) installation of a new coal boiler was already available (Philipp 1980a,b). This methodology is extended to consider gas-coal, water-coal and gas-coal-water conversions. The total conversion cost per kilowatt for the various back-out options that should be of general applicability are summarized in Table 1.3. Breakdowns of these costs are given in Chapter 5. The third column of Table 1.3 gives annual savings of a 200 megawatt unit following such a conversion, and the fourth column gives the payback period for the capital costs of conversion. It is seen that these results favor the gas-coal option, to a large extent with respect to the coal-oil mixture option, and to varying lesser extents with respect to the other options.

Chapter 6, Quantitative Inputs for Economic Analyses, presents the inputs used in the final economic analyses and projects and quantifies the inflation rate and oil, gas, and coal growth rates. Figure 1.5 summarizes the essential features of the time dependences incorporated into the study. The large differences anticipated between oil and coal prices account for the major savings attendant to the displacement of oil by gas and coal. The price of gas which only supplies about 30 percent of the energy does not greatly influence the results.

Chapter 7, A Detailed Economic Analysis of Conversion Alternatives, discusses (1) the costs of capital, (2) the discount rate, (3) shutdown periods, (4) future fuel prices, and (5) payback period. The discussion is of general applicability and sets down the basis for our specific Florida calculations.

Chapter 8, Assessment of the Gas-Coal Conversion Option for Florida, presents the specific results of our analyses of the Florida utility system. The principal results are summarized in Table 1.4. A savings of 2.5 billion dollars per year is obtained by the conversion of 12,678 megawatts of oil boiler capacity. The reduction in annual oil use by Florida utilities would be about 0.2 million barrels of oil per day.

Chapters 5, 6, 7, and 8 constitute the core of the detailed economic analyses on the conversion of utility oil boilers in Florida to gas and

Table 1.3 Total Conversion Costs for Various Options

	Percent Coal Energy	Total Conversion Cost $/KW	Total Annual Cost 10^6\$/yr	Differential Annual Cost 10^6\$/yr	Payback Period
Oil	0	--	46.0	Base	--
COM	30	84	43.9	-2.1	3.3
Dual NFGD Coal	80	144	29.5	-16.5	1.5
Oil FGD	80	216	34.4	-11.6	2.4
NCFBWFGD$^+$	100	376	36.0	-10.0	3.2
Gas/Coal	70	127	25.8	-20.2	1.2
Coal/Water	100	132	31.3*	-14.7	1.5
Gas-Coal/Water	70	132	29.4*	-16.6	1.4

$^+$ denotes new coal fired boiler with flue gas desulfurization.

* Includes extra energy cost of water evaporation and fine coal grind but not cost of peaking unit to replace lost capacity.

Table 1.4 Summary of Economic Gain for Gas-Coal Conversion of Florida Oil Boilers

	Oil Base Case	Gas-Coal
Capacity (MW)	12,678	12,678
Conversion Costs (million dollars)		1429
Annualized Capital Cost (15 yrs @ 11%)		199
Annualized (extra O and M costs)		29
Total Annualized Costs	4,824	2,294
Savings from base case		2,530
Production Cost/KWH	7.2¢	3.4¢

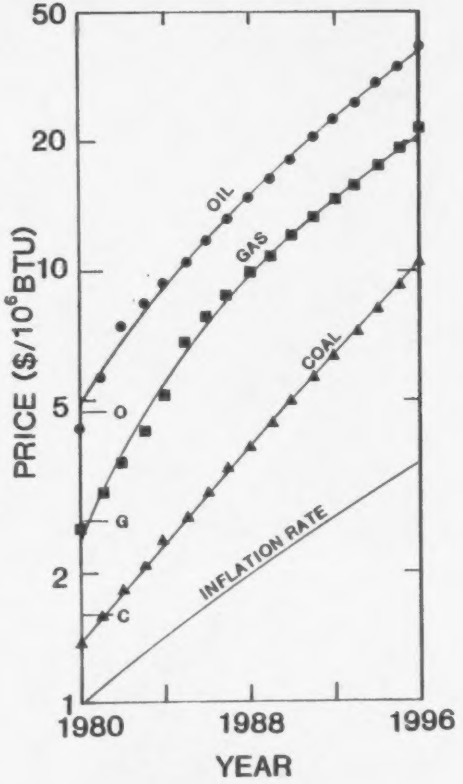

Fig. 1.5 Price Rate Projections for Oil, Gas and Coal and Inflation from AGA Tera Model The symbols O, G, and C indicate 1980 prices used in Chapter 8.

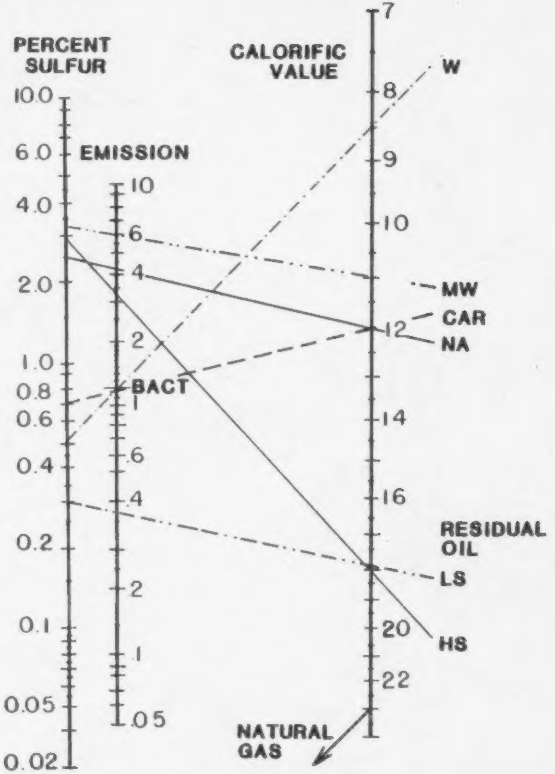
PERCENT SULFUR
10.0
6.0
4.0
2.0
1.0
0.8
0.6
0.4
0.2
0.1
0.05
0.02
EMISSION
10
6
4
2
BACT
1
.6
.4
2
1
.05
CALORIFIC VALUE
7
8
9
10
12
14
16
20
22
W
MW
CAR
NA
RESIDUAL OIL
LS
HS
NATURAL GAS

Fig. 1.6 Nomogram for Calculating Emission Levels (adapted from EPA-600/9-77-017). Emission levels are in $\sigma = 1$ lb $SO_2/10^6$ BTU. Calorific values are in 10^3 BTU/lb.

coal burning carried out under the AGA-ICAAS study. The fact that the pay-off of the gas-coal-oil back-out approach was much bigger than had been expected stimulated us to broaden our work to serve a national audience. To a large extent the other chapters of this monograph were developed for this purpose.

1.7 Air Quality Impacts

Chapter 9: Air Quality Impacts, considers the environmental impacts of oil-to-coal conversions that can arise because of the vastly greater ash content of coal and the somewhat greater sulfur content of many coals. Table 1.5 gives the characteristics of several of the major fuel groups, along with their energy release, ash and SO_2 emissions. The installation of a flue gas desulfurization (FGD) unit is extremely costly, and there usually is little space to accommodate it in a preexisting plant. Fortunately, it is possible to achieve acceptable levels of SO_2 by four simple and relatively inexpensive measures. These include

(1) the choice of a high quality or moderate quality coal
(2) the use of physical coal cleaning (PC)
(3) the burning of coal with natural gas (NG)
(4) the use of burner or boiler scrubbing (BS).

Figure 1.6 is a nomogram for calculating the emission levels for any fuel when the percentage sulfur by weight and the calorific values (in 10^3 BTU/lb) are specified. The lines illustrate the major fuel groups listed in Table 1.5. Note that high sulfur residual oil leads to much greater emissions than two of the coal groups (CAR and W) and also gives emissions comparable to the third group (NA). Thus, while the reductions factors achievable by measures 2, 3 and 4 are moderate, the combined reduction factor can bring a unit without FGD into the range achievable with Best Available Control Technology (BACT), which is usually accepted as 1.2 lbs SO_2/million BTU. This is illustrated in Table 1.6, which shows the effects of the reduction factors R(PC), R(NG), and R(BS) upon the final emission for various coal grades as defined by the normal emissions.

The technology for coping with particulates using precipitators or bag houses and ash handling boiler modifications is quite advanced and the costs of refitting, while large, are tolerable. In addition, it should be

Table 1.5 Major Fuel Groups Uncontrolled SO_2 and TSP Emission Rates

FUEL	BTU CONTENT BTU/UNIT	%S	EMISSION	ASH %	EMISSION
COAL					
Northern Appalachian (NA)	12,000/LB	2.5	4.17 σ	14.0	7.58 π
Central Appalachian & Rockies (CAR)	12,000/LB	0.7	1.17 σ	12.0	6.50 π
Midwestern (MW)	11,000/LB	3.3	6.0 σ	11.0	6.50 π
Western (W)	8,500/LB	0.5	1.18 σ	9.0	6.88 π
RESIDUAL OIL					
High Sulfur (HS)	150,560/GAL	3.0	3.14 σ	-	0.053 π
Low Sulfur (LS)	146,430/GAL	0.3	0.31 σ	-	0.055 π
NATURAL GAS (NG)	1,027/FT^3		0.0006 σ	-	<0.015 π

σ denotes lbs $SO_2/10^6$BTU, π denotes lbs particulates/10^6BTU.
Adapted from ICF, Inc. Boilers System Cost Estimates, Table II-3, 1978

Table 1.6 Emissions (in lbs $SO_2/10^6$ BTU) for Various Coals, Physical Cleanings, Natural Gas and Burner Scrubbing.

R(PC)	R(NG)	R(BS)	A(1.2σ)	B(2.4σ)	C(4.2σ)	D(6.0σ)
1.0	1.0	1.0	1.	2.4	4.2	6.0
		.6	0.72	1.44	2.52	3.6
	.75	1.0	0.9	1.8	3.15	4.5
		.6	0.54	1.08	1.89	2.7
	.60	1.0	0.72	1.44	2.52	3.6
		.6	0.43	0.86	1.51	2.16
	.50	1.0	0.6	1.2	2.1	3.0
		.6	0.36	0.72	1.26	1.8
.6	1.0	1.0	0.72	1.44	2.52	3.6
		.6	0.43	0.86	1.51	2.16
	.75	1.0	0.54	1.08	1.89	2.7
		.6	0.32	0.65	1.13	1.62
	.60	1.0	0.43	0.86	1.51	2.6
		.6	0.26	0.52	0.91	1.18
	.50	1.0	0.36	0.72	1.26	1.8
		.6	0.22	0.43	0.76	1.08

possible to minimize ash problems by using a first stage gas-coal combustor designed to remove ash. This approach will be discussed further in Chapter 11 on research and development needs for gas-coal displacement of oil.

1.8 National Assessment

Chapter 10, A National Assessment of Oil Displacement using Gas and Coal Burning, may be placed in perspective by Figure 1.1 and Table 1.7, which gives the trend of U.S. energy supply and disposition. The national capacity of utility oil boilers corresponding to the categories in our Florida study constitutes 63,279 megawatts. Proportioning this to the 12,678 Florida oil capacity and the 2.5 billion dollar per year Florida consumer saving, we arrive at a 12.5 billion dollar per year national savings. The 0.2 μ (million barrels of oil per day) saved by Florida extrapolates to 1.0 μ. The value of this savings to the U.S. as a country is, of course, greater than the consumer savings since we are keeping our dollars for gas and coal at home.

The industrial oil use of 3.4 μ constitutes an even more tempting alternative fuels target. Fortunately, many of the considerations applicable to smaller utility boilers are directly applicable to large industrial boilers. Furthermore, a number of national studies addressing the question of "Replacing Oil and Natural Gas by Coal in Industry" can be utilized to help provide approximate answers to the question of "Replacing Oil by Coal and Natural Gas in Industry".

On the basis of our Florida utilities study, it is not unreasonable to assume that 80 percent of the energy consumable by large industrial boilers can be displaced by gas and coal. The smaller boiler question is more difficult. However, using prior studies and taking advantage of the large proportion of natural gas used and recent developments in stoker-fired fluidized bed combustors and tri-fuel boilers, we show that it should be possible to displace most of the oil used by small industrial boilers.

Table 1.7 U.S. Energy Supply and Disposition

(Quadrillion Btu)

Activity and Fuel	1960	1965	1970	1975	1976	1977	1978	1979	1980[a]
Supply									
Production									
Crude Oil and Lease Condensate	14.93	16.52	20.40	17.73	17.26	17.45	18.43	18.10	18.25
Natural Gas Plant Liquids	1.46	1.88	2.51	2.37	2.33	2.33	2.25	2.29	2.27
Natural Gas[b]	12.66	15.78	21.67	19.64	19.48	19.57	19.49	20.08	19.70
Coal[c]	11.12	13.38	15.06	15.19	15.85	15.83	15.04	17.65	18.88
Nuclear Power	0.01	0.04	0.24	1.90	2.11	2.70	2.98	2.75	2.70
Hydropower	1.60	2.06	2.63	3.15	2.98	2.33	2.96	2.95	2.91
Other[d]	(l)	0.01	0.02	0.07	0.08	0.08	0.07	0.09	0.11
Total Production	41.78	49.67	62.51	60.06	60.09	60.29	61.20	63.91	64.82
Imports									
Crude Oil[e]	2.20	2.65	2.81	8.72	11.24	14.03	13.46	13.83	11.06
Refined Petroleum Products[f]	1.80	2.75	4.66	4.23	4.43	4.73	4.36	4.11	3.38
Natural Gas	0.16	0.47	0.85	0.96	0.99	1.04	0.99	1.30	1.03
Other[g]	0.07	0.04	0.07	0.19	0.18	0.30	0.44	0.39	0.28
Total Imports	4.23	5.92	8.39	14.11	16.84	20.09	19.26	19.62	15.75
Adjustments[h]	–0.44	–0.74	–1.41	–1.08	–0.21	–1.96	–0.36	–1.66	–0.54
Total Supply	45.57	54.85	69.49	73.09	76.72	78.43	80.10	81.87	80.03
Disposition									
Consumption									
Refined Petroleum Products[i]	19.92	23.25	29.52	32.73	35.17	37.12	37.97	37.12	34.25
Natural Gas[b]	12.39	15.77	21.79	19.95	20.35	19.93	20.00	20.67	20.44
Coal[e]	10.12	11.89	12.66	12.82	13.73	13.96	13.85	15.11	15.67
Nuclear Power	0.01	0.04	0.24	1.90	2.11	2.70	2.98	2.75	2.70
Hydropower[j]	1.65	2.06	2.65	3.22	3.07	2.51	3.16	3.17	3.13
Other[d]	(l)	0.01	0.02	0.07	0.08	0.08	0.07	0.09	0.11
Net Imports of Coal Coke	–0.01	–0.02	–0.06	0.01	(l)	0.02	0.13	0.07	–0.04
Total Consumption	44.08	52.99	66.83	70.71	74.51	76.33	78.15	78.97	76.27
Exports									
Coal[c]	1.02	1.38	1.94	1.79	1.62	1.47	1.10	1.78	2.47
Other[k]	0.46	0.48	0.73	0.60	0.59	0.63	0.85	1.12	1.29
Total Exports	1.48	1.86	2.66	2.39	2.21	2.10	1.95	2.90	3.76
Total Disposition	45.57	54.85	69.49	73.09	76.72	78.43	80.10	81.87	80.03

[a] Preliminary.
[b] Dry marketed gas.
[c] Includes bituminous coal, lignite, and anthracite.
[d] Geothermal, wood, refuse, and other vegetal fuels used for electricity generation at utilities.
[e] Includes imports of crude oil for the Strategic Petroleum Reserve.
[f] Also includes imports of unfinished oils and natural gas plant liquids.
[g] Includes bituminous coal, lignite, and anthracite, as well as coke made from coal, and hydropower.
[h] A balancing item. Includes stock changes, losses, gains, miscellaneous blending compounds, unaccounted for supply, and anthracite shipped overseas to U.S. Armed Forces.
[i] Refined petroleum products supplied includes natural gas plant liquids and crude oil burned as fuel.
[j] Includes industrial generation of hydropower and net electricity imports.
[k] Includes crude oil, refined petroleum products, natural gas, coke made from coal, and hydropower.
[l] Less than 0.005 quadrillion Btu.
Note: The sum of components may not equal the total due to independent rounding.

SOURCE: U.S. Department of Energy 1980 Annual Report to Congress DOE/EIA-0173 (80), March 1981.

The prospects for displacing oil in the process heat industrial sector are also quite good. In addition coal can be used directly as a chemical feedstock in place of oil. Furthermore biomass (Zaborsky 1981) and botanochemical crops can substitute for the use of many petroleum-derived products (Buchanan and Duke 1981).

Chapter 10 also contains a discussion that suggests that the U.S. might be able to make substantial inroads into the oil used in the commercial sector and the residential sector (at least for apartment houses and condominiums). Table 1.8 gives best, low and high estimates of oil displacement levels that might be achieved in the utility, industrial, commercial and residential sectors by vigorous programs directed toward gas-coal replacement of oil. Note that if the high estimates were realized we would practically have achieved National Energy Independence, the goal of our nation since 1974.

Finally, we should note that while concern for the United States' flagging economy has been the driving force behind this entire effort, the international aspects of oil-displacement by gas and coal should not go unnoticed. Most immediately Europe appears to be going ahead with a pipeline to draw upon natural gas from the U.S.S.R. Several countries in Europe also have large coal reserves. Many other countries of the world that are deficient in oil reserves have coal and natural gas. The economic and environmental advantages of gas-coal burning in place of oil would be accessible to such countries as well.

Table 1.8 National Potential for Oil Displacement in Million Barrels of Oil per Day

	Current Use	Best Estimate	Low	High
Utilities	1.4	1.0	0.8	1.2
Industry	3.4	2.0	1.6	2.6
Commercial	1.4	0.8	0.5	1.0
Residential	1.6	0.6	0.4	0.7
	7.8	4.4	3.3	5.5

CHAPTER 11:

RESEARCH AND DEVELOPMENT NEEDS

Burning gas-coal mixtures is not a research topic that a scientist would naturally choose in the pursuit of truth and knowledge. It is too complicated a combustion system to be of great interest from a fundamental standpoint. However, it is a reasonable topic, somewhat outside the pale of topics currently under study in major combustion programs, which might appropriately be pursued in connection with an attempt to solve an important national problem. In this case, the problem is to reduce our large negative balance of payments associated with the importation of oil from the OPEC Cartel.

11.1 Existing Research Programs

Resource geologists have for some time predicted the exhaustion of the oil and natural gas reserves of the world and particularly the United States. The Arab oil embargo of 1973 and the subsequent price increases by the OPEC Cartel from around 2 dollars per barrel in 1972 to around 32 dollars per barrel in 1981 have focused considerable attention on our depletion problem. The economic problems associated with these price increases have prompted major expansions in our research and development programs directed toward finding alternative energy sources. The earlier national efforts tended to concentrate on nonfossil sources such as breeder reactors, controlled fusion, solar energy, geothermal energy sources, ocean thermal sources, etc. As our immediate economic problems became more severe, it has become generally recognized that coal represents the only large domestic energy resource which this country can draw upon quickly to help correct its economic problems (Energy Research Advisory Board, 1980; Landsberg, et al. 1979; Office of Technology Assessment, 1979; National Academy of Sciences, 1980; ICAAS, Coal Burning Issues, 1980).

Much of the emphasis of the coal related research and development work has been directed towards finding ways of mitigating the environmental impacts usually attributed to the use of coal. In addition to oil displacement the multibillion dollar synthetic liquid and gaseous fuels program initiated by President Carter was, in part, motivated by this emphasis. The development of clean coal solids, using physical and chemical coal cleaning, and flue gas desulfurization systems are essentially attempts to clean up the coal act.

11.2 Current Oil Backout Programs

A federal program has been underway for several years "encouraging" the restoration to coal use of boilers originally designed for coal burning but converted to oil during the the days of cheap oil (Fuel Use Act, 1978). With the near completion of this program attention naturally falls upon the question of retrofitting to coal, boilers originally designed for oil. Conventional wisdom in the United States had it that this is not economically feasible. For example the Regional Utility System of Gainesville, Florida, which placed an order for a 240 megawatt oil boiler in 1974, suffered severe cost penalties when at the beginning of the construction phase, it completely changed over to a 240 megawatt coal system under federal mandate. ICAAS's detailed involvement in the environmental impacts of utility boilers along with its consideration of coal use goes back to this period (ICAAS, 1975).

The commissioner and staff of the Kwinana Utility Station near Perth, Australia faced with exponentially increasing oil prices and apparently unconstrained by U.S. conventional wisdom, (Kirkwood et al., 1978; Treadgold, Engineers Australia 1979; Energy Commission News, March 1979) chose to retrofit two 200 megawatt oil boilers still in the construction phase to dual coal/oil use. Since then planning to retrofit oil boilers to burn coal directly has also become an acceptable engineering activity in the United States.

11.3 Pumpable Coal Based Substitutes for Oil

While the dual coal/oil solution is also under consideration in Tucson, Arizona (CE 1980), the trend at this time in this country is toward the development of pumpable coal based substitutes for oil. The coal/oil mixture approach which has this feature has thus far received the greatest attention (Cook 1980). However, it would appear now that the economic benefits of this approach do not significantly exceed costs and this approach will probably begin to lose the priority that it has been given in U.S. R & D efforts.

The next highest priority for investigation by the U.S. Department of Energy and also by the Electric Power Research Institute appears to be the coal-water approach. This is another pumpable fuel arrangement which has the advantage that the pulverizing of the coal and the fuel mixing can be carried out outside the immediate space of the oil boiler itself--thus simplifying retrofitting problems. More importantly, it reduces immediate capital costs which is a major problem of the utility industry at this time (Brigham and Gapenski, CBI 1980).

Certain questions, however, can be raised concerning the coal-water approach which remain to be answered. In the first place, the fact that a good quality coal by itself is a marginal oil boiler fuel, except possibly for a generously sized oil boiler designed with coal retrofitability in mind, would be exacerbated by the large water content of the injected coal-water slurry. Presently a slurry consisting of 40 percent water and 60 percent coal is viewed as optimum. Such a mixture would have a decreased calorific content, of the order of 8,000 BTU/lb. which is comparable to lignite. The vaporization and heat capacity loss (between inlet water temperature and flue gas temperature) corresponds to about 480 BTU/lb which corresponds about to a 5 percent energy loss in hot water vapor out the stack. More importantly, a large derating might be expected (see Fig. 4.1) since such a mixture could only be burned at a low power density (usually called space heating rate). Some compensation to avoid this lower power density could be accomplished by using a higher degree of pulverization, i.e., 90 percent through 325 mesh but this is costly in pulverizer energy and pulverizer machinery wear. Other compensations possibly can be made by incorporating new ways of increasing the power density such as used in gas turbine reactors. Another problem might be the adverse effect upon flue gas inerting systems (Smoot et al. 1980) designed to minimize pulverizer fires and explosions. Water vapor is also known to promote the conversion of sulfur to sulfuric acid and the extra corrosion potential of a coal-water slurry could be deleterious to flue gas inerting system and other systems of the retrofitted oil boiler.

The use of a pumpable slurry of 60 percent pulverized coal, 30 percent methanol and 10 percent water has been discussed (Capehart et al. CBI 1980a). The calorific context of methanol is 9800 BTU/lb which makes it a much more favorable liquid coal carrier than water, from a combustion standpoint. Whether its cost, in $/BTU makes it competitive and whether the derating problem is substantially mitagated remains to be determined.

11.4 Gas-Coal Burning Configurations

The economic and/or environmental advantages of the gas-coal approach with respect to the coal-water approach must ultimately be determined by demonstration projects which, of course, will require time and money. To determine how best to spend this time and money it would be helpful to sketch the general characteristics of possible gas-coal burning arrangements. In retrofitting, design options are limited by the space availability, foundation capabilities, detailed boiler design, etc. Many aspects of these problems have already been overcome in the Kwinana project and in the proposed Irvington conversion of the Tucson Gas, Electric Light and Power Co. where "shoe horn" approaches were used.

Direct Gas-Coal Firing

Figure 11.1 illustrates the main features of coal boiler arrangement apart from the fuel input and burner. Obviously a retrofit should move as far as possible toward a coal designed boiler. Figure 11.2 illustrates, on an enlarged scale, the gas-coal feed system and a burner which if space is available could be placed immediately at the boiler face. If space is not available, the coal pulverizing components shown in Figure 11.2 could be located at the nearest available space-e.g. some 100-200 feet distant. The combination would be similar to the dual coal/oil configuration except that the retention of the oil capability would be unnecessary since during

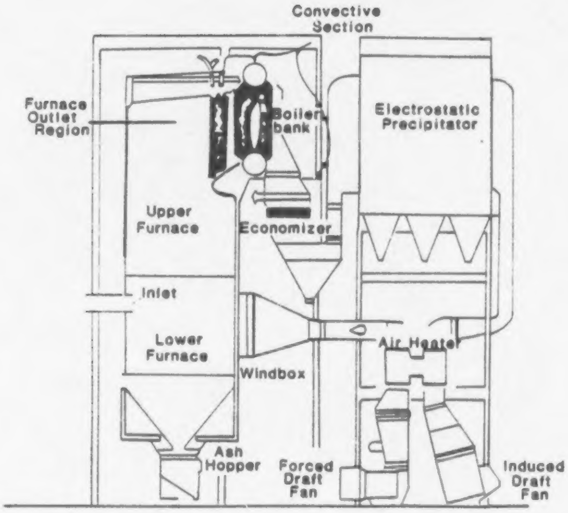
Convective Section
Furnace Outlet Region
Boiler bank
Electrostatic Precipitator
Upper Furnace
Economizer
Inlet
Lower Furnace
Air Heater
Windbox
Ash Hopper
Forced Draft Fan
Induced Draft Fan

Fig. 11.1 Schematic Diagram of a Pulverized Coal-Fired Electric Utility Boiler (Adapted from Hardesty and Pohl 1979, Sandia Laboratories Report 78-8804 and Coal Study Report, Cooper et al. 1981).

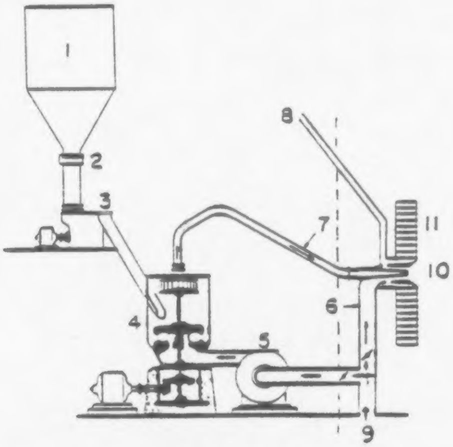
1
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Fig. 11.2 System for Direct Firing of Pulverized Coal with Gas (1) Coarse Coal Bin (2) Gate (3) Feeder (4) Pulverizer (5) Fan (6) Secondary Air (7) Pulverized Coal and Primary Air (8) Gas (9) Heated Air (10) Burner (11) Boiler. (Adapted from Figure 3.14(a) Essenhigh, 1979 Chapter 3, Coal Combustion in Coal Conversion Technology, Wen and Lee eds. Addison-Wesley, 1979).

peak power needs the proportion of natural gas would simply be increased, say to 40 percent. Thus the gas-coal approach avoids the necessity of maintaining the residual oil system in a state of readiness (by keeping the oil warm) or reliance on the use of expensive peaking units. The disadvantage of this direct gas-coal injection system is the large amount of ash injected into the oil boiler. The required boiler modifications to accommodate this ash should be similar to those used at Kwinana and planned for at Irvington.

11.4.2 Two Stage Gas-Coal Firing

A second gas-coal option is illustrated in Fig. 11.3 which shows input equipment which replaces that shown in Fig. 11.2. This equipment includes a first stage combustion system designed to remove as much of the coal ash as possible and to inject into the boiler for after-burning a fuel rich hot mixture of CO, coal volatiles, and unburned natural gas. The boiler itself, fed by secondary and tertiary air, would burn this mixture along with additional natural gas. If boiler front space is limited, the equipment illustrated in Fig. 11.3 could be placed immediately outside the boiler area. Blowers and high temperature insulated pipes would be used to transport the gaseous products for afterburning in the oil boiler with natural gas enhancement. The distance between the pulverizer and first stage combustion chamber-ash separator might be used to advantage to allow further means for separating any residual ash before injecting the hot gaseous combustion products into the boiler. By working below ash melting temperatures it should be possible to minimize slagging problems in both combustion chambers and in the transport tubes and also NO_x problems associated with atmospheric nitrogen. By working the first chamber at fuel rich conditions NO_x problems due to chemically bound coal nitrogen can be substantially reduced (Hall and Cichanowicz 1980, CE 1981 p. 13-9).

Another advantage of the first stage combustion chamber approach is that it affords the possiblity of carrying out some SO_x scrubbing such as referred to in Section 9.2. If such suppression techniques could also serve to convert the ash into a useable product such as a fertilizer, this would enhance the benefits of the conversion in relation to the costs.

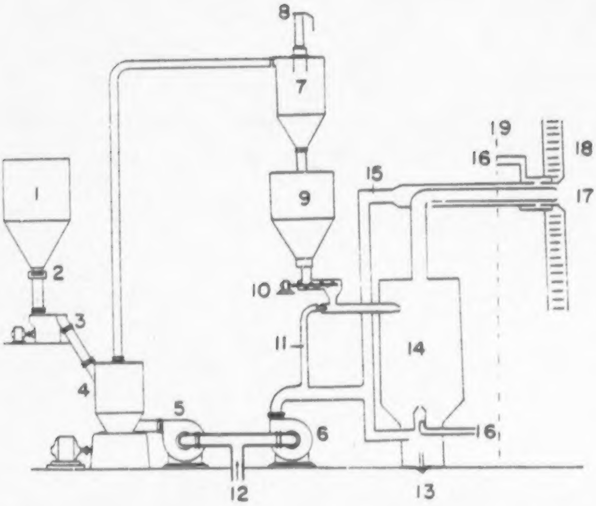


Fig. 11.3 Systems for Two Stage Pulverized Coal-Gas Firing (1) Coarse Coal Bin (2) Gate (3) Feeder (4) Pulverizer (5) Pulverizer Fan (6) Burner Fan (7) Cyclone Separator (8) Air Vent (9) Pulverized Coal Storage Bin (10) Pulverized Coal Feeder (11) Primary Air (12) Air Supply (13) Ash Outlet (14) First State Combustion Chamber-Ash Separator (15) Secondary Air (16) Gas Inlets (17) Coal-Gas Burner (18) Boiler (19) Pipe Extension if needed. (Adapted from Fig. 3.14(b) Essenhigh, 1979, Chapter 3, Coal Combustion in Coal Conversion Technology, Wen and Lee eds).

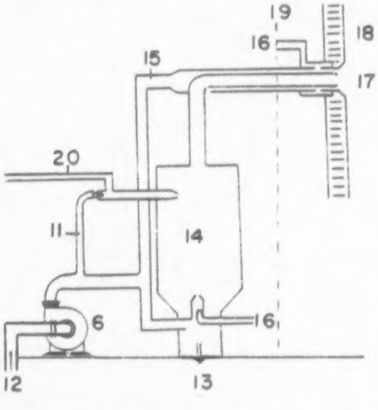


Fig. 11.4 Schematic System for Two Stage Coal-Water-Gas Firing. Here (20) Represents Input from Coal-Water Pipeline and all Remaining Numbers are the same as in Fig. 11.3.

Finally, it should be mentioned that the first stage gas-coal combustion chamber approach affords an opportunity to start with a coarser pulverized coal since by the use of vortex motion the residence time in the burning zone could be prolonged to equal the burnout time of the coarser particles.

11.4.3 Gas-Coal-Water System

In arrangements based upon the gas-coal-water approach, the pulverizer and coal-water mixing system could be as far away as the nearest port facility. In direct firing of the coal water slurry a dual fuel burner similar to that used in gas-oil burners could be used in an arrangement similar to that illustrated in Figure 11.2. The natural gas facilitates the water evaporation, increases the calorific value of the fuel thereby increasing the achievable power density beyond the capabilities of the coal-water fuel.

A first stage combustion chamber-gasifier-ash separator such as is illustrated in Figure 11.4 might be used in the gas-coal-water approach. The first stage would effectively be a generator of H_2 + CO, i.e. producer gas. The overall arrangement would minimize the boiler derating problem and provide other advantages such as a capability for directly using the coarse (80 percent through 14 mesh; granulated sugar sized) particles used in coal slurry pipelines. Such an approach would greatly reduce the capital costs required for an individual oil boiler retrofit in exchange for increased fuel costs. The approach could be implemented in a metropolitan area even before long distance coal pipelines are built.

The two gas-coal configurations and the gas-coal-water configuration just discussed suggest a specific applied research and development efforts which will be discussed next.

11.5 Research Needs

Section 11.4 visualizes three broad types of systems for retrofitting oil boilers to burn coal with natural gas or to burn a coal-water mixture with natural gas. If we accept the development of such systems as a short term goal where should we apply research efforts to hasten the implementation of such conversions? Four research topics stand out.

1. Studies of the ash formation process in interacting gas-coal flames.
2. Studies of the characteristic of afterburning flames which can be created from various gas-coal primary flames.
3. Studies of the influence of additives in the primary stage upon the production of SO_x, NO_x and upon other characteristics of the afterburning flame.
4. Studies of the influence of the water in the gas-coal-water approach upon the ash formation process, the characteristics of the afterburning flame for various inputs and for various types of additives.

11.5.1 Ash Formation in Interacting Gas-Coal Flames

To some extent there already is a background of scientific research on gas-coal flames, in studies of the burning of coal having high volatile content. Several recent reviews of coal pyrolysis have appeared [Horton (1979), Malte and Rees (1979), Wen and Dutta (1979), Essenhigh 1979] as a general background which can serve for gas-coal studies. The primary types of experiments needed for applications are experiments which resemble those arising in practical gas-coal combustion systems. The experimenter would control the quality of the pulverized coal, its fineness and flow field, and the natural gas and air inputs. Heating rates and final temperature, chemical and spectral emissions of the resultant flame should be measured. Flame temperature might be controlled with an insulating jacket or a water jacket with various flow rates.

Spectroscopic and photometric measurements and ash collection could be used to establish the influence of the higher heating rates expected in gas-coal flames upon devolatilization, and the combustion of the char.

Existing kinetic models of pyrolysis should be generalized to allow for the externally introduced methane. The pyrolysis equations should be coupled with transport equations to arrive at a model of the temperature, volatiles and combustion product evolution under realistic coal, gas and air input rates.

Fly ash formation in pulverized coal combustion is a very complex phenomena (Ulrich et al., 1976; Flagan, 1977). The initial heating and devolatilization of coal particles and char burnout usually results in a skeletal char structure with mineral inclusions. At about 50% burnout the hot molten ash inclusions tend to fuse into an agglomeration which accelerates in the last 25% of char burnout. Later in the burnout the char structure fractures, resulting in fly-ash fragments. How will this fly-ash evolution change when the coal particles are burning with natural gas? The higher temperature achievable should, through Arrhenius factors, increase all reaction rates and speed up the entire chain of combustion processes. On the other hand competition for oxygen might have a slowing effect. The influence of the proportions of coal, gas and air would be important to understand. The influence of flow field arrangements such as vortex motion which extends residence time should be studied and quantitative descriptions should be developed. Ash collection and classification with various flow field arrangement should be carried out in conjunction with modeling to infer the parameters of the fly-ash formation processes.

11.5.2 Afterburning Studies

A major simplification in the retrofitting of oil boilers could be accomplished if a first-stage combustion chamber can be developed to serve a multiple role: (1) pyrolyze the coal; (2) promote the ash formation process and separate out a large fraction of the ash; (3) deliver a fuel rich mixture of intermediate gaseous combustion products to a second stage combustion chamber for afterburning; (4) provide for the introduction of SO_x and NO_x suppressing additives.

The spectral output of afterburning flames which is expected to be richer in transient species than the flame of the first stage combustion chamber should be analyzed. Furthermore, the relationships between the particulate sizes emanating from the first stage chamber and the conditions within this chamber should be investigated by examining the spectra and the gaseous and particle emissions of the afterburning flame.

The overall objective of afterburning flame studies is to be able to predict the characteristics of the combustible mixture emitted by the first stage combustion chamber. A theoretical model of these relationships should be developed which would be useful in predicting the characteristics of boiler flames in practical two-stage combustion arrangements.

11.5.3 The Influence of Additives Upon Flame Characteristics and Afterburning Characteristics

Desulfurization in fluidized bed coal combustion systems has been developed to a high level of sophistication. The possiblity of carrying out desulfurization in a pulverized coal boiler or a first stage combustion chamber has received much less attention. What is needed is to investigate the influence of various flame additives upon SO_x and NO_x emissions. Of particular interest would be the use of inexpensive additives such as limestone, dolomite, or waste phosphate slime, which would transform the ash into useful commercial fertilizers or other commercial products.

11.5.4 Coal-Water-Gas Gasifiers

A primary stage coal-water-gas combustor has the interesting extra dimension of high water content in the input fuel. Under appropriate circumstances this should foster the formation of synfuel or producer gas (H_2 + CO). The intensive work which has already been carried out on gasifiers (see Table 3.4) should find applications here. Studies which bridge the gap between gasification programs without methane augmentation and the mixed gas-coal-water gasification would be very useful. Of particular interest would be whether, with the gas-coal-water combustor, one could utilize directly the coarser grind now under consideration in coal water slurries. If it can be burned efficiently this would make it possible to greatly reduce the local capital costs of conversion. Essentially the conversion would consist of the installation of several package coal-water-gas gasifiers with high temperature piping arranged to feed the output into the boiler. Ash removal facilities will still be needed but this is only about 10 percent of the problem posed by the coal facilities which are no longer needed.

11.5.5 General Studies of Gas-Solids Combustion and Ash Separation

The underlying thesis of this monograph is that burning coal with gas upgrades the coal as a combustible material to the point of being usable as a higher quality fuel such as oil. Since the United States has excellent reserves of coal but is economically suffering from insufficent oil reserves, the use of moderate quantities of natural gas in defense of the quality of American life can be viewed as constituting a higher use, perhaps even higher than the use of gas for home water heaters. In view of the more favorable gas supply picture the possibility of upgrading other solid fuels such a brown coal, lignite, peat, wood chips, bark chips, peletized urban wastes (Hanson 1980) so that each of them can replace a higher quality fuel also warrants consideration. General experimental investigations of gas-solid fuel combustion could serve a great variety of purposes. The development of a theoretical model for gas-solid combustion would provide a valuable basis for many applications not only for retrofitting existing boilers and furnaces but also for the design of new systems. First stage combustion chambers can be designed for many solid fuels.

The concept of a first stage natural gas-solid fuel compustor-ash-separator is a fruitful area for applied research. The concept has several features of a cyclone burner (BW 1978 Chap. 11) but it would appear best to design to achieve a dry ash, most of which is separated out by the techniques used in cyclone dust separators, before the hot combustion gases are injected into the boiler. On the other hand a high temperature first stage combustion chamber, like a cyclone but arranged to separate out the molten ash before injection into the boiler, might prove as efficient or more efficient for many fuels. Cool baffles in the gaseous transport system might stop small molten ash droplets entrained with the combustion gases. The air mixing techniques used in recent distributed mixing burners (Hall and Cichanowicz 1980, Rees et al. 1980, CE 1981, p. 13-9) might overcome the NO_x problem of ordinary cyclones.

The new feature of mixing natural gas into the first stage combustion zones and into the boiler combustion zones provides additional flexibility which should challenge the imagination of combustion scientists and engineers concerned either with the design of new boilers or retrofitting an existing boiler.

The characteristics of the ash and its possible commercial uses will be important in the studies of gas-solids combustion and ash separation.

11.5.6 Basic Research

The foregoing specific topics are motivated by a need to reduce uncertainties in gas-coal or gas-coal-water systems envisaged in Section 11.4. To the extent that these types of systems have not been considered in the formulation of existing Department of Energy, Environmental Protection Agency, Electric Power Research Institute, Gas Research Institute or National Coal Research Institute research programs, they represent nonconventional combustion research programs. Very recently a report has been submitted to the American Physical Society by a study group on Research Planning for Coal Utilization and Synthetic Fuel Production (Cooper et al. 1981). This study constitutes a broad nonconventional view of coal utilization needs. The report is directed towards a two-fold audience: physicists who may become active in coal research and DOE sponsors and others in the "user community". The report emphasizes areas of coal research where the contributions of technical and conceptual approaches of physics would be especially relevant. The report discusses coal-oil mixtures and coal-water systems but does not consider gas-coal systems. Nevertheless, the execution of these research recommendations would greatly advance understanding of topics which would be helpful toward the development of practical gas-coal systems. Table 11.1 is a list (unranked) of the principal research recommendations of this committee.

Table 11.1 Principal Research Recommendations (unranked)
(The American Physical Society Coal Study Group Cooper et al. 1981)

- support for physics research in the area of coal utilization make provision for a non-negligible percentage of highly novel, even speculative, approaches to outstanding applied problems.
- presently available and developing techniques be applied to the determination of chemical structural features of coals, including hydroaromatic and aromatic cluster configurations, functional groups, and molecular weight distributions.
- systematic analyses of the physical properties of coal to elucidate the pore structure of coal particles including pore shapes and pore size distributions.
- strenuous efforts to develop better dynamic models of advanced coal processes.
- initiation of a carefully planned program to evaluate presently available instruments, and where necessary to develop new instruments, usable both for systematic collection of data on advanced coal processes and for incorporation into control systems for these processes.
- intensive effort on theoretical work needed to formulate problems concerned with multiphase flow behavior, and to develop innovative computer simulations of such behavior.
- an extensive research effort to understand the effects of coal conversion and combustion environments on materials of construction (alloys, refractory ceramics, composites, etc.), including long duration exposure to the process environment.
- pursuing experimental and theoretical investigations to delineate the phenomena in size reduction processes, such as grinding and chemical comminution.
- further work to bring sophisticated spectroscopic methods of solid state and surface physics to bear on systems with compositions, and conditions of pressure and temperature, as closely akin as possible to those used in practical heterogeneous metal catalysis for fuel synthesis, i.e., starting from syngas (H_2 and CO) mixtures obtained from coal gasification.
- increased emphasis on understanding and exploiting the properties of size and shape selective catalysts.
- the establishment of a sample bank of well selected, characterized, and preserved coal samples, available to research and analytical groups. This should be preceded by research sufficient to verify the chosen storage technique(s).
- establishment of a program to gain fundamental understanding of processes for coal utilization and synthetic fuel production. This would focus on the development and testing of theoretical models and of process control techniques, together with the development of instrumentation for acquisition of the data necessary for this purpose.

11.6 Development Needs

As we have indicated, applied and basic research are greatly needed to develop an understanding of the basic laws governing practical gas-coal systems. However, much is already known about the burning of high volatile pulverized coal which can be used as a basis for the design and construction of prototype gas-coal systems while basic and applied research programs are being carried out.

Thus, the development of a practical first stage gas-coal combustion chamber with efficient ash and sulfur removal features can be carried out on an empirical basis using knowledge acquired in the gasification program, by experience with cyclone burners (BW 1978) and distributed mixing burners (CE 1981). The primary objective would be to develop a gasifier-ash separator to feed clean gaseous fuel into a preexisting boiler. The acid test of success is whether the first stage combustion products could be injected into a practical second stage furnace, process heater, kiln, or boiler. Firing a small first stage combustor (say 5 million BTU/hr) into a ceramic kiln would be particularly useful since glazes are very sensitive to residual ash. If, for example, the system could be fired with high quality stoneware without affecting the glazes, this would be indicative of success with boilers.

Experience on a moderate scale using the output of a primary combustor should provide information upon which to base retrofitting modifications for industrial level boilers or furnaces for institutional heating systems. There is a background on the use of gas and coal in limestone and brick furnaces which could also be helpful in this regard. Experience with industrial level gas-coal systems would also provide a basis for the development of scaling laws which would be useful for the design of a large range of gas-coal burner sizes. Conventional wisdom has it that pulverized coal systems are only economically competitive at large power levels (i.e., > 50,000,000 BTU/hr). On the other hand, conventional wisdom has not considered the gas-coal concept and it would be worthwhile to reexamine the cross-over point at which a pulverized coal system becomes economicaly competitive, when it is augmented by gas.

Many other technical developments would be helpful in speeding the realization of the displacement of oil by burning coal with gas. For example, if for reasons of space limitations the first stage combustion chamber is placed off-site then there is a need for high temperature insulated piping to deliver the hot fuel to the boiler. The large spatial separation between the first and second stages opens up the possibility of incorporating additional ash reduction devices enroute. The introduction of cyclone separators, loops or baffles could further reduce ash in the first stage flue gas.

There are a number of utility boilers in this country designed for coal firing but also having oil and/or gas burning capability (Kidder, Peabody and Company 1979, Plank 1981). This dual or tri-fuel capability was incorporate for start up purposes or to take advantage of the lowest price fuel and to have emissions flexibility from an environmental standpoint. These systems might serve as the immediately available test facilities for large scale testing of the gas-coal-oil displacement approach. If by burning coal with gas the steam output could be increased substantially above the rated output for coal alone (assuming no boiler tube or other limitations are exceeded) it would suggest that burning coal with gas in an oil boiler could be carried out above the coal power limit.

Many other practical developments such as control systems, safety systems, ash disposal systems, etc. will be needed to implement a gas-coal conversion program. The dual fuel character affords an extra degree of freedom which can be used very gainfully in such systems. By taking advantage of the greater ease of gas regulation and the latest developments in sensing devices and computer control systems, a world of new possibilities for automation exists. The dual fuel in itself affords a degree of redundancy which promotes reliability, which is a major consideration in the utility, industrial, commercial, and residential uses of combustion.

11.7 Interdisciplinary Research Needs

This chapter has concentrated on technical aspects of gas-coal burning since the highest priority question is whether we can "fool" a preexisting oil boiler into burning coal with gas at or near its design power capacity. Once this is established and technical objections are answered there obviously will be needs for research on the environmental-health-economic-financial-political-socio-legal and other interdisciplinary aspects of a transition from oil to gas-coal burning. In this connection the chapters on these topics in Coal Burning Issues (Urone, Fahien, Taylor et al., Bolch, Woltz and Street, Schlenker and Jaeger, Green and Rio, Brigham and Gapenski, Rosenbaum, Little and Capehart CBI 1980) also are relevant to burning coal with gas. For example Chapter 18, Federal Regulatory and Legal Aspects, is of special concern since the Public Utilities and Industrial Fuel Use Act of 1978 is an obstacle to burning coal with gas. How do we go about revising a federal law which now appears to have been based upon erroneous estimates of future natural gas production? The political side of this question and other questions such as addressed in Chapter 17, Coal and the States: A Public Choice Perspective are also very relevant.

In this latter connection the recent work by the political scientists Wildavsky and Tenenbaum (1981) entitled the Politics of Mistrust raises some very disturbing questions. They hypothesize that for most of this century, American energy policy has been a polarized political issue in which policy differences are rooted in deep conflicts over values and hence energy policy debates cannot be resolved by better information and analysis. While this is very disheartening to the editor of this work he finds hope in their note that during the two World Wars there was enough consensus about the purposes of energy policy to mute devisiveness and mistrust. Perhaps the great economic problems which this country now faces will be viewed as the "equivalent of war". Hopefully then an objective evaluation of options based upon new information and analyses might be achieved and a consensus as to the common good might again be reached.

References

American Gas Association, Gas Supply Committee, *The Gas Energy Supply Outlook: 1980-2000*, Arlington, Va., October 1980 (as revised December 1981).

American Gas Association, Economic Comparison of Oil Scrubbed Coal, and Select Gas Use with Coal in New England Power Plants in *Energy Analysis*, American Gas Association, Arlington, VA., 1981.

Babcock & Wilcox, Steam: *Its Generation and Use*, 39th Edition, by Babcock & Wilcox Company, 1978.

Bolch, W.E., Solid Waste and Trace Elements Impact, Chapter 12, pp. 231-248, in *Coal Burning Issues*, ICAAS, 1980.

Brigham, F. and C. Gapenski, Financing Capacity Growth and Coal Conversions in the Electric Utility Industry, Chapter 16, In *Coal Burning Issues*, ICAAS, pp. 331-342, 1980.

Buchanan, R. A. and Duke, J.A., Botanochemicals Crops, pg. 157-179, Handbook of Biosolar Resources Vol. II, O. R. Zaborsky, Ed., C.R.C. Press, Boca Raton, Florida, 1981.

Capehart, B.L., O'Connor, J. D. and Denty, W. M., Coal Transportation, Chapter 4, pp. 71-94. In *Coal Burning Issues*, ICAAS, 1980.

Combustion Engineering, Inc., *Combustion, Fossil Power Systems*, J. G. Singer (Ed.), Windsor, CT., 1981.

Combustion Engineering, Inc., Tucson Electric Power Co., Irvington Station, Attachment 1, November 17, 1980.

Cook M. C., Operating Florida Power and Light Company's Sanford Plant on Coal-Oil Mixture, presented at the Seventh Annual International Conference on Coal Gasification, Liquefaction, and Conversion to Electricity, University of Pittsburgh, August 5-7, 1980.

Cooper, R. B. et al., Report to American Physical Society by Study Groups on Reasearch Planning for Coal Utilization and Synthetic Fuel Production, Reviews of Modern Physics, 53, 4, Part II, October, 1981.

Department of Energy, Fuel Use Act: Final Environmental Impact Statement, DOE/EIS-0038, April 1979.

Department of Energy, 1980 Annual Report to Congress, Volume 3: *Forecasts*, DOE/EIA-0173 (80)3, March 13, 1981.

Ehrlich, S., Drenker, S., and Manfred, R., *Coal Use in Boilers Designed for Oil and Gas Firing*, presented at American Power Conference, Chicago, Illinois, April 21-23, 1980.

Energy Research Advisory Board, 1980.

Environmental Protection Agency, Coal Cleaning with Scrubbing for Sulfur Control: An Engineering Economical Survey, EPA-600/9-77-017, August, 1977.

Essenhigh, R. H., Coal Combustion, pp. 171-312, In Coal Conversion Technology, C. Y. Wen and E. A. Lee, (Ed.), Addison - Wesley, Reading, Massachusetts, 1979.

Fahien, R. W., Air Pollutant Dispersion Modeling, Chapter 10, pp. 187-202. In Coal Burning Issues, ICAAS, 1980.

Flagan, R. C., Ash Particle Formation in Pulverized Coal Combustion, Paper No. 77-4, Spring Meeting of the Western States Section, The Combustion Institute, Seattle, Wash., 1977.

Florida, Governor's Energy Office, Forecasts of Energy Consumption in Florida, 1980-2000, September, 1981.

Glenn, R., Coal-Water Slurry Systems for Oil Design Power Plants, EPRI FP-1164, Combustion Processes, Inc., 1979.

Green A. E. S., The Middle Ultraviolet: Its Science and Technology, Wiley, New York, 1966.

Green, A. E. S., Rich Phenomena in the Middle Ultraviolet, Optics News, 7, 3, p. 77, Invited Paper, National Meeting of the Optical Society of America, October 26-30, 1981.

Green, A.E.S. and Green, B.A.S., in Proposal by ICAAS on Mitigation of the Impact of Increased Coal Use in the Southeast (MIICUSE), to U.S. Department of Energy, p. 11, February 1980.

Green, A.E.S., Green, B.A.S. Description of Initial Firings of Propane and Pulverized Coal at the Dragon Fire and Clay Co. Facilities, in proposal to U.S. Department of Energy, dated March, 1981.

Green, A.E.S. and Jones, J.R., Gas-Coal Burning Interactions and Addendum to IICUF, issued by ICAAS, March 15, 1981.

Green, A.E.S., and Rio, D.E., Quantitative Public Policy Assessments, Chapter 15, pp. 303-330, In Coal Burning Issues, ICAAS, 1980.

Green A.E.S., Ellerbrock, M.J. Schwartz, J.M., Kuntz, S.J., Zeiler, B. and Crimmons, N.T., The Conversion of Utilitly Oil Boilers in Florida to Gas and Coal Burning, ICAAS, University of Florida, Gainesville, August, 1981.

Green, A.E.S. (Ed.), An Alternative to Oil: Burning Coal with Gas, University Presses of Florida, Gainesville, Florida, 1982.

Hall, R. E. and Cichanowicz, J.E., Proceedings of the Joint Symposium on Stationary Combustion NO_x Control, EPA/EPRI-IERL-RTP-10831, October, 1980.

Hanson, H.P., Chapter 7, pp. 135-154, In Coal Burning Issues, ICAAS, 1980.

Hardesty, D.R., and Pohl, J.H., Sandia Laboratory Report 78-8804, 1979.

Horton, M.D., Fast Pyrolysis, Chapter 8, Pulverized Coal Combustion and Gasification, Plenum Press, New York and London, (1979).

Horvath, J.J., Vaidya, D.B., and Green, A.E.S., Observations of OH Emission (0,0 band) in a Methane-Caol Dust Flame, Optics News, 7, 3, p. 78, Oct 26-30, 1981.

ICAAS, Review of Gainesville/Alachua County. Regional Utilities Board's Application for Site Certification of Deerhaven Unit No. 2, prepared by Florida Department of Pollution Control by ICAAS, A.E.S. Green, P.I., Gainesville, Florida, February, 1975.

ICAAS, Coal Burning Issues, Green, A.E.S., (Ed.), University Presses of Florida, Gainesville, Florida, January, 1980.

ICAAS, The Impact of Increased Coal Use in Florida (IICUF), Green, A.E.S., (Ed.), The University of Florida, Gainesville, Florida, November, 1980.

ICF, Inc., Boiler System Cost Estimates, Chapter 2, 1978.

Kidder, Peabody and Co., Fossil Power Status Reports, 1979.

Kirkwood, J. B., Kregg, D.H., and Schoenwetter, H. D., Conversion to Coal of Gas/Oil-fired Boilers, Power Engineering, p. 66, July, 1978.

Kirkwood, J. B., Commissioner's Corner, Energy Commission News, Western Australia, March, 1979.

Landsberg, H. H. et al., Energy: The Next Twenty Years, Resources for the Future Study Group, Ford Foundation, Ballinger Publishing Co., Cambridge, Mass., 1979.

Little, J.W. and Capehart, L.C., Federal Regulatory and Legal Aspects, Chapter 18, pp. 359-381, In Coal Burning Issues, ICAAS, 1980.

Malte, P. C. and Rees, D.P., Mechanisms and Kinetics of Pollutant Formation During Reaction of Pulverized Coal, Chapter 11, Pulverized-Coal Combustion and Gasification, Plenum Press, New York and London, (1979).

National Academy of Science. Energy in Transition 1985-2010, Final Report of the Committee on Nuclear and Alternative Energy Systems, W.H. Freeman and Co., San Francisco, California, 1980.

Office of Technology Assessment, The Direct Use of Coal, Prospects, and Problems of Production and Combustion, Library of Congress, 79-600071, Washington, D.C., 1979.

Philipp, J. and Kregg, D., Conversion from Oil to Coal-firing, City of Gainesville, Department of Utilities, June 17, 1980.

Philipp, J., Oil to Coal Conversion Options, Burns and Roe, Inc., Paper presented at EPRI/Florida Power and Light Seminar on Use of Coal in Oil-Design Utility Boilers, Lake Buena Vista, Florida, December 2-4, 1980.

Plank, D., Manager Engineering Dept. City Utilities of Springfield, Missouri, telephone conversation, Sept. 1981.

Powerplant and Industrial Fuel Use Act of 1978, Public Law 95-620, 9th Congress, November 9, 1978.

Rees, D.P., Lee, J., Brienza, A.R., and Heap, M.P., The Development of Distributed Mixing Pulverized Coal Burners, Proceedings of hte Joint Symposium on Stationary Combustion NO_x Control, EPA/EPRI, 5, 249-273, October, 1980.

Rosenbaum, W.A., Coal and the States: A Public Choice Perspective, Chapter 17, pp. 343-358. In Coal Burning Issues, ICAAS, 1980.

Schlenker, E.H., and Jaeger, M.J., Health Effects of Air Pollution Resulting from Coal Combustion, Chapter 14, pp. 277-302. In Coal Burning Issues, ICAAS, 1980.

Schlesinger, B., Natural Gas Can Help Coal Burn Cleaner, American Chemical Society Journal, 14, 1067-1071, 1980.

Smoot L.D., G.J. Geoffrey, J.N. Cannon, R.P. Cutler, D.E. Schramm, Pulverized Coal Power Plant Fires and Explosions, Summary Report Part III, Brigham Young University, Chemical Engineering Department, October 15, 1980.

Taylor, KE., Chameides, W.L., and Green, A.E.S., Atmospheric Modifications, Chapter 11, pp. 203-230. In Coal Burning Issues, ICAAS, 1980.

Tennessee Gas Transmission Company, Energy 1981-2000, Houston, Texas, p. 18, August, 1981,

Treadgold, J., World Lead in Oil-to-Coal Conversion, Engineers Australia, June 15, 1979.

Ulrich, G.D., Milnes, B.A., and Subramanian, N.S., Particle Growth in Flames, II, Experimental Results for Silica Particles, Combustion Science Technology 14, 243-249, 1976.

Urone, P. and Kenney, M.A., Atmospheric Pollution, Chapter 9, pp. 169-188. In Coal Burning Issues, ICAAS, 1980.

Wen C. Y. and Dutta, S., Rates of Coal Pyrolysis and Gasification Reactions, Chapter 2, Coal Conversion Technology, C.Y. Wen and E.A. Lee (Eds.), Addison-Wesley Publishing Co., Reading, Mass., pp. 57-170, 1979.

Wen, C. Y. and Lee, E.S., Coal Conversion Technology, Addision-Wesley Publisning Co., Reading, Mass., 1979.

Wildavsky, A., and Tenenbaum, E., The Politics of Mistrust, Sage, Beverly Hills, California, 1981.

Wilkinson, P.L., American Gas Association Letter to A.E.S. Green, dated November 25, 1981.

Woltz, S.S., and Street, J.J., Agriculture, Chapter 13, pp. 249-276, In Coal Burning Issues, ICAAS, 1980.

Zaborsky, O.R. (Ed.-in-chief), CRC Handbook of Biosolar Resources, 2, Resource Material, National Science Foundation, Washington, DC, T.A. McClure and E.S. Lipinsky (Eds.), Battelle Columbus Laboratories, Columbus, Ohio, CRC Press, Inc., Boca Raton, Florida, 1981.

Mr. Nelson [presiding]. Dr. Green, how is the coal-oil mixture working? Do I understand that Florida Power & Light has a plant that is under operation at Sanford that is still experimental, is that correct?

Dr. Green. Well, the Sanford plant has been burning coal and oil. I don't now whether the program still continues, in approximately 60-percent oil, 40-percent coal, by weight. If you consider the fact that oil is about 18,000 Btu per pound and coal is about 12,000 Btu per pound, the fuel turns out to be 70-percent oil energy and 30-percent coal energy. So you are getting a lot of the headaches of coal and you are not getting very much of a payoff. I think they are coming to that conclusion but I shouldn't speak for them.

I might say in the gas-coal proportion blend, we are talking 70-percent coal energy and 30-percent gas energy. That is where the great payoff is, in that simple set of proportions. It turns out the capital costs for retrofitting amortized over 15 years are not very great, as compared to the fuel savings. Returning to your question I think my answer is that FPL is looking in other directions right now.

Incidentally, our experiments used the Sanford coal in our fast combustion experiments of gas and coal.

Mr. Nelson. It wasn't too long ago that we had a shortage of gas in various parts of the Nation. What is the practicality of mixing coal and gas with possible future shortages?

Dr. Green. We have turned out a book on this subject and my written statement is largely a summary of the book. First, we are not talking a lot of gas. We are talking like 2 trillion cubic feet out of 20 trillion cubic feet, our national annual production.

Now, in 1978 we thought we were going way downhill in gas production from 20 trillion to 10 trillion cubic by the year 2000. However now almost everybody recognizes we can hold the line at about 20 trillion cubic feet per year until the year 2000. Now we are burning gas alone in boilers for generating raw electricity. I think that's a wasteful use of gas. I think if we only burned the gas-coal blend, we would save enough in utilities and industry, for this particular use. So by using what we have in a more optimum way a gas shortage should not really be a problem.

Mr. Fuqua [presiding]. Dr. Jefferies, we will hear from you now.

Dr. Jefferies. Mr. Chairman, members of the committee, I appreciate this opportunity to discuss GE's views on coal research. We are a major supplier of equipment to all sectors of the coal business, we produce and transport coal through our subsidiary, Utah International, we offer energy system design services to coal users, and, of course, we burn some coal in our own factories.

This afternoon I would like to present our views on industry's role in coal research. I will focus on the two questions in chart 2; namely, what coal research does industry perform with its own funds, and when should Government funded research be performed by industry.

I will then conclude by drawing implications for the present budgetary environment.

As noted in chart 3, industry performs two broad classes of research with its own funds: research in support of product development, and exploratory research. Chart 4 outlines an example of research in support of product development.

GE has had a longstanding interest in the use of coal or coal-derived fuels in gas turbines. In 1972 we began a research project on coal gasification. Our early research was directed at gasifier components. This led to the construction of a bench scale and later, a pilot scale gasifier. In operating these units, it became evident that research on gas cleanup was required—research that eventually led to a pilot scale clean-up system. Tests performed on this pilot system indicated the need for yet more research, this time on system control, which is now underway.

The point here is that we have a product interest in gasifier combined cycle power plants, and because we do, we have funded considerable research over a long period of time directed at that product.

It is important to note here that contrary to common perceptions, research continues during the entire product development cycle. The figure at the left of chart 5 depicts an often used but overly simplistic model of the research and development process. In it, basic research generates the initial idea, and then plays an insignificant role. In our experience, the neat progression from basic research to applied research, to development, and so on, rarely occurs.

As depicted in the more realistic model on the right, the development cycle does involve a general progression from a new idea or discovery to a commercial product, but as development proceeds, it is often necessary to return to basic research to resolve unexpected problems and to continue product evolution.

In addition to research in support of product development, industry also funds exploratory research in areas of possible future business interest. Chart 6 describes one of our exploratory projects in which we applied computed tomography—a medical diagnostic technique—to coal research. As you know, computed tomography has had a dramatic impact on the field of medicine, providing highly detailed images of internal organs.

We applied this new analytical tool to coal research in the hope of gaining new insights into the fundamentals of coal. Although we had no specific commercial applications in mind, we did think that our involvement in coal research might lead to new business opportunities.

We funded several scientists for 3 years on this project, and from a purely scientific perspective, the work was successful. It led to science's first views of the inside of coal undergoing chemical reactions. So far, we have identified one possible product application of this work.

This example illustrates some of the characteristics of exploratory research. As you can see in chart 7, the general purpose of exploratory research is to investigate new ideas and fast moving technologies that could lead to new business opportunities in areas of interest to the company. The payoff from this work is highly uncertain, but industry is often willing to fund it because it is not overly expensive. It holds open the possibility of breakthroughs, and at the same time, protects companies from being surprised by their competitors.

The general point, then, is that industry does fund research—if that research is in support of product development or if it explores new ideas at relatively low cost. However, moderating oil prices and the general economic environment are now forcing many companies to back away from their energy related product commitments in favor of other areas in which the returns appear to be higher and the payback periods shorter. As a result, the amount of coal research that industry is willing to fund can be expected to decline.

In addition to research with its own funds, industry performs substantial amounts of research with Government funds. This leads to my second question—when should Government-funded research be performed by industry?

One case in which Government-funded research usually should be performed by industry is when the technology being developed is intended for commercial use. The reasons for this are shown in chart 8. First, companies in the market sector for which the technology is intended are familiar with the market constraints that the space technology must ultimately satisfy to become commercially viable.

Second, by assigning such projects to industry, Government avoids the need to transfer the technology once it is developed.

On this question of technology transfer, it is often suggested that the role of Government labs is to perform R&D through the early stages of development, and then to transfer the technology to industry, which will complete the technology's development. One of the reasons technology transfer is so difficult to accomplish is that this separation of the early and late stages of development is somewhat arbitrary. As I discussed earlier, basic research is an integral part of the entire product development process. So again, when a technology is intended for a specific market, there usually are advantages to assigning its development to firms in that market.

Let me add a caveat, however. We need to distinguish betweeen companies that have a possible interest in either manufacturing or using the technology to be developed, and companies that take on federally funded R&D solely in order to generate revenue. No advantage accrues from allocating Government projects intended for the market to the latter group. Once the project is completed, it will still have to be transferred to the marketplace.

It seems to me that the clearest indication that a company has a potential interest in actually using a technology for which feasibility has been established is its willingness to invest its own funds in the technology's development.

Turning to chart 9, a second case in which Government-funded research should be performed by industry, is when industry possesses a special or unique technical capability with respect to the project. For example, GE has a unique process evaluation facility which can be used to conduct research on the environmental emissions from coal gasification combined cycle powerplants. As another example, GE, given its background and experience, is particularly well suited to do research on the compatibility of coal fuels with gas turbines.

Turning now to chart 10, let me conclude by drawing some implications for the constrained budgetary environment that we now face. I have argued that industry is in fact willing to fund its own coal research, or any research for that matter, if the research is in support of product development, or if it is a relatively inexpensive exploration of new areas of possible business interest. Industry will not fund research projects dropped by the Government that fall outside these two categories. Indeed, at present, industry appears to be narrowing rather than expanding its commitments to new coal technologies.

I have also presented my views on when Government research projects are best assigned to industry. In a constrained budgetary environment, we must be more efficient in how we use our funds. There are substantial efficiencies to be gained in allocating Government funds in accordance with the following rules:

First, assign research projects intended for a specific market to firms in that market that demonstrate an interest in manufacturing or using the technology.

Second, take advantage of existing facilities and expertise instead of duplicating them.

Mr. Chairman, thank you again for this opportunity to present my views, and I will do my best to answer any questions you may have.

[The attached charts 1-10 to Dr. Jefferies' statement follow:]

INDUSTRY'S ROLE IN PERFORMING COAL RESEARCH

Hearings on Coal Research
Subcommittee on Energy Development
and Applications
House Committee on
Science and Technology
May 18, 1982

M.J. Jefferies
Manager, Energy Science and Engineering
General Electric Company
Corporate Research and Development

Chart 1

INDUSTRY'S ROLE IN PERFORMING COAL RESEARCH

- What coal research does industry perform with its own funds?
- When should government funded research be performed by industry?

Chart 2

WHAT COAL RESEARCH DOES INDUSTRY PERFORM WITH ITS OWN FUNDS?

- Research in support of product development
- Exploratory research

Chart 3

WHAT COAL RESEARCH DOES INDUSTRY PERFORM WITH ITS OWN FUNDS?

RESEARCH IN SUPPORT OF PRODUCT DEVELOPMENT – AN EXAMPLE

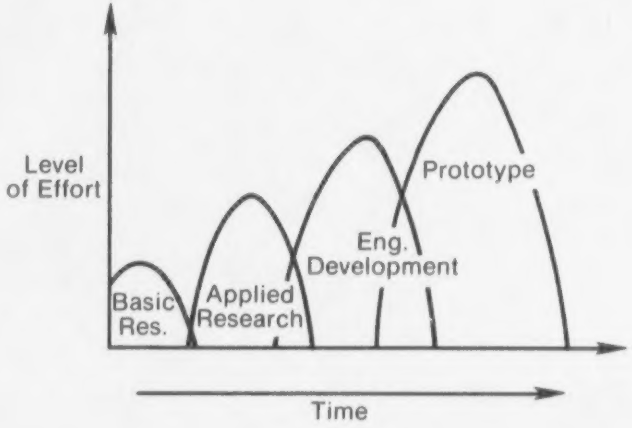
- General Electric funded research on gasification combined cycle power plants
  - Coal gasification work started in 1972
  - Early research directed at gasifier components
  - Construction of bench-scale and pilot units
  - Operation of units revealed need for research on gas cleanup
  - Pilot cleanup system developed (with government funding)
  - System tests indicated need for further research on system control

Chart 4

WHAT COAL RESEARCH DOES INDUSTRY PERFORM WITH ITS OWN FUNDS?

RESEARCH IN SUPPORT OF PRODUCT DEVELOPMENT

- Industrial research is and should be integrated with product development


Level of Effort
Basic Res.
Applied Research
Eng. Development
Prototype
Time

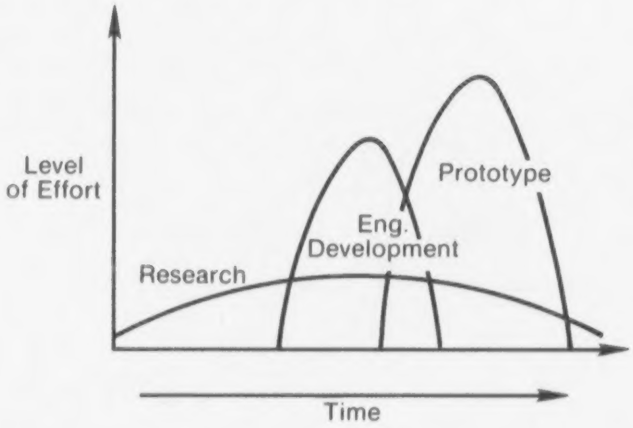

Level of Effort
Research
Eng. Development
Prototype
Time

Chart 5

WHAT COAL RESEARCH DOES INDUSTRY PERFORM WITH ITS OWN FUNDS?

EXPLORATORY RESEARCH – AN EXAMPLE

- General Electric funded research on computed tomography of coal
  - New idea: application of a medical diagnostic technique to coal research
  - Practical implications unclear, but further basic understanding of coal considered to have potential for high leverage in applications
  - Three year effort involving several scientists
  - Work was scientifically successful, allowing first views into coal undergoing chemical reactions
  - Possible spinoff application identified

Chart 6

WHAT COAL RESEARCH DOES INDUSTRY PERFORM WITH ITS OWN FUNDS?

EXPLORATORY RESEARCH

- Focuses on promising new ideas
    - High uncertainty but relatively low costs
    - Possible "breakthroughs"
    - Avoid surprises by competitors

Chart 7

WHEN SHOULD GOVERNMENT FUNDED RESEARCH BE PERFORMED BY INDUSTRY?

WHEN IT IS INTENDED FOR COMMERCIAL USE

- Companies in the market sector understand the market constraints
- The need to transfer the technology is avoided
  - The research and product development are integrated
- These advantages do not apply to companies that perform government R&D solely to generate revenue
  - A measure of a company's interest is a willingness to invest its own funds—assuming technical feasibility

Chart 8

WHEN SHOULD GOVERNMENT FUNDED RESEARCH BE PERFORMED BY INDUSTRY?

WHEN INDUSTRY HAS A SPECIAL TECHNICAL CAPABILITY

- Areas of research that require special expertise
- Areas of research that require special facilities

Chart 9

CONCLUSION

- **Industry funds research which supports product development or research which is exploratory**
    - Industry will not fund research dropped by the government that falls outside these categories
    - Industry appears to be narrowing its commitment to new coal technologies
- **Industry has a special role in performing government funded research**
    - When the research is aimed at a technology intended for commercial use
    - When industry has a special technical advantage

Chart 10

Mr. FUQUA. Thank you very much, Dr. Jefferies.

Now we will hear from you, Dr. Kolb.

Dr. KOLB. Mr. Chairman, thank you for inviting me to testify at this review and reassessment of the Department of Energy's fossil energy program dealing with coal utilization research. My comments today will be addressed to research accomplishments, concerns and opportunities in the area of direct coal combustion or pyrolysis of coal to low grade synthetic gas for use in direct combustion. I will not be addressing research on the issues of obtaining high quality synthetic fuels or chemical feedstocks from coal.

While I hope to address coal combustion research from a general point of view, it is fair to note that my major perspective is that of director of the applied sciences division at Aerodyne Research, a small high-technology business performing contract research and development for Government and industrial programs.

For the past 6 years, under ERDA and DOE funding, we have been engaged in studies designed to improve combustion efficiency, reduce hot gas corrosion, and improve the exhaust pollutant characteristics of advanced coal burnig technologies. We have a demonstrated and published record of fundamental contributions to the basic phenomena underpinning technologies such as fluidized bed coal combustors, coal gasifiers, coal combustion fired turbines, and coal fired magnetohydrodynamic generators. We are currently under contract to the Office of Coal Utilization through the Morgantown Energy Technology Center, and the Office of Magnetohydrodynamics, both in the DOE fossil energy program.

My personal perspective also includes the problems of university-based research, particularly at Harvard University and the Massachusetts Institute of Technology, where I have current research staff appointments and participate in a number of joint programs.

I think it is important to recognize first that our problem is not getting coal to burn in order to produce process heat or generate electricity. Some of our forebears were warming themselves beside a coal grate, not only before we recognized that we have a national energy problem, but even before our Republic was founded. Indeed, if you're willing to believe NBC, last night you saw Marco Polo discovering the Mongols burning coal in the 13th century.

Our problem is learning how to burn coal, an intrinsically nasty and dirty fuel, in a clean, safe, and efficient manner. Because of coal's high nitrogen, sulfur, and trace metal content and its high carbon-to-hydrogen ratio, thoughtless burning leads to high levels of nitrogen oxides, sulfur oxides, soot, and both acid and heavy metal-laden ash particulates, all of which can severely aggravate environmental problems, including photochemical smog, acid rain, and haze.

Furthermore, the alkali metals, halogens, and sulfur found in coal can cause severe corrosion and fouling problems to the combustion system itself, leading to expensive equipment failure and costly down time, thus severely affecting the economic utility of coal-fired systems. Highly efficient combustion must often be carried out at high temperature which further aggravates many environmental and materials problems.

Fortunately, a number of advanced coal-fired systems for electrical generation, including direct fired magnetohydrodynamic generators and advanced combined cycle systems, which utilize some combination of fluidized bed combustors and gasifiers with gas turbine or molten carbonate fuel cells, do hold out the promise of safe and clean coal utilization if properly developed. Properly designed fluidized bed combustors and multiple staged pulverized coal combustors should also allow the efficient generation of clean process heat and steam for industrial processes.

However, the successful design and utilization of these promising advanced systems requires a firm base of research, not only in the chemical kinetics and fluid mechanics of coal combustion, but in materials research to design high temperature, reliable components; in basic corrosion research to identify the chemistry and physics of materials failure; in diagnostic and control development to allow real-time measurements of combustion characteristics and continuous adjustment of combustion conditions; and in hot gas stream homogeneous and heterogeneous processes to allow quantification and removal of corrosive, erosive, or environmentally dangerous combustion exhaust species.

While the need to perform the crucial baseline research necessary for environmentally safe and economically sound coal combustion systems was often submerged in DOE's injudicious rush to build large, glamorous development and demonstration projects, a great deal of progress has been made during the past 5 years.

Under the direction of research-oriented program managers in the fossil energy program, and with some supplemental funding from DOE's basic energy sciences program, the Environmental Protection Agency, and the National Science Foundation, we have learned a lot about key problems. Progress in understanding fundamental combustion phenomena such as gaseous and mineral volatilization kinetics, char burnout kinetics, fuel nitrogen, and nitrogen oxide kinetics, slag thermochemistry, slag heat and electrical conductivity, and ash condensation mechanisms has been gratifying. Major progress in the development of combustion diagnostics for gaseous and particulate species, temperature, and combustion plasma conductivity have also been made. Advanced diagnostics involving lasers in various ways to measure differential absorption and various scattering and fluorescence phenomena, have allowed very key new insights into combustion dynamics. Finally, advances in materials chemistry and processing has led to new classes of ceramic and metallic materials more capable of withstanding high temperatures, particulate erosion, and alkali sulfate corrosion.

The scientists and research engineers who have accomplished these advances are widely dispersed among university laboratories—MIT, Stanford, and Berkeley are examples, large industrial laboratories, small industrial laboratories, and nonprofit institutions, as well as Government laboratories, both inside and outside the DOE framework. They have reason to be proud of their work, but in most cases they have finished only a portion of the research necessary for real system design and demonstration. In some key areas we are only now learning the proper questions to ask, and we are a long way from having obtained the right answers.

As to concerns, coal combustion researchers in all types of laboratories share real concerns about the future of their field—despite administration and congressional statements that long-term, high-risk energy research is now the focus of the Government effort.

During fiscal year 1982, it is my impression that many fossil energy programs were forced to direct funds originally earmarked for various Advanced Research and Technology Development, (AR&TD) type programs, to support either ongoing demonstration projects that were not canceled, or to pay termination costs for closing projects that were canceled.

I am very concerned that similar actions will occur in fiscal year 1983, particular in view of the drastic cut the administration has proposed for fossil energy in general and AR&TD type projects in particular. I believe Dr. Solomon in earlier testimony stated some of the programs that were being zeroed out. Without funds, even the best scientists can make little progress.

A second area of concern involves program management. A great deal of credit for past accomplishments should be given to those DOE program managers who were dedicated to providing key baseline understanding, even when the power and prestige flowed to those prematurely advocating large demonstration projects.

However, it is not clear that the Assistant Secretary of Fossil Energy's plan to drastically reduce the fossil energy staff includes the identification and retention of these vital staff members. Indeed, given the dynamics of a civil service-controlled reduction in force, it is not even clear that much could be done to protect those highly competent research-oriented program managers even if they were identified. Buying and managing high-quality, effective research is a tough job, and the wrong people may well end up in charge. We have wasted a lot of money in the past in this country by having the programs planned and managed by people whose capabilities and horizon were not adequate to the task.

Furthermore, shifting responsibility to the energy technology centers or the national laboratories will not solve the problem. The staffs of the former are often oriented to large projects of mainly engineering nature, while the staffs of the national labs are largely research scientists, and neither type of facility is overly blessed, at least in my opinion, with research-oriented and trained program managers.

Further, it is a fact of life that a large percentage of the funds funneled through any government laboratory stick in place and are not necessarily available to fund the people with the best research records or the most productive ideas.

Finally, a major concern involves the appropriations procedure in Congress and the executive branch. Failure to set appropriation levels until well after the start of the fiscal year, coupled with further delays involving program authorization within DOE, inevitably lead to funding dropouts of many months for non-Government laboratories. The resulting stop and go of funds, with its disruptive effect on both research and morale, has become an annual occurrence and is driving many of the best people into other fields of endeavor. The continual loss of good people, many from sheer aggravation, to military or other nonenergy research, will eventually cripple all progress toward safe, efficient, and economic coal utilization. It also results in a very inefficient use of funds.

In fact, in some cases where funds are finally available, they remain within the DOE laboratory system simply because there is not enough time in the fiscal year for a program manager to do anything other than transfer them within the system. There is simply no time to write a contract to an industrial, university, or nonprofit laboratory.

Despite the imperfections of the system, we have learned a lot and many coal combustion research groups of high quality exist in various laboratories. I would like to make the following recommendations for future programs involving coal combustion research:

One, that appropriate long-term research programs involving coal combustion kinetics and fluid dynamics, pollutant formation and removal, trace species chemistry and recovery, combustion induced corrosion and fouling, advanced materials design and testing, advanced combustion diagnostic and control design and testing, and combustion system mathematical modeling be defined and supported at appropriate levels. These programs can all be built on a solid base of past accomplishments.

Second, I would like to recommend that the Assistant Secretary for Fossil Energy be directed to identify and retain sufficient research oriented program management to successfully design, implement, and monitor these research programs.

Third, that it be recognized that key coal combustion research competence exists in a variety of university, industrial, nonprofit and governmental laboratories, and that DOE program management be instructed not to duplicate capabilities that exist in laboratories not managed or controlled by DOE, that they be asked not to establish competing groups or facilities in energy technology centers or national laboratories that duplicate existing competence or facilities.

Fourth, that the Congress and the Administration attempt to avoid starving non-government laboratories out of the field by agreeing to program appropriations well in advance of the fiscal year start and to promote rational research planning and investment in research facilities by establishing longer term minimum funding levels for coal combustion research programs.

Thank you very much.

Mr. FUQUA. Thank you very much, Dr. Kolb.

Dr. Green, in 1980 the EPA had a study on the cost benefits of physically clean coal and noted that institutional barriers and a lack of appreciation of all of the benefits of clean coal have retarded its adoption.

Do you agree that institutional barriers exist, and if so, what kind are they?

Dr. GREEN. The ones that I might be familiar with are the requirement for flue gas to sulfurization, which in the retrofitting of existing oil boilers becomes a very formidable problem. There is usually no space for it. In my opinion, one could achieve the ends of installing a flue gas sulfurizer by using physically coal cleaning and other simple measures. The removal of 50 percent of the ash and 50 percent of the sulfur is quite possible at modest cost. Thus you should start out with a good grade of coal, physically clean the coal, carry out some scrubbing in the boiler itself—and also use my notion to mix in a little gas. Thus we could bypass institutional barriers to retrofitting existing oil boilers.

So I think you are correct in saying there have been barriers.

Mr. **Fuqua**. Do you think cleaning is an economic alternative to the flue gas scrubbing?

Dr. **Green**. Well, even if you did flue gas scrubbing, physical coal cleaning will produce economic benefits. It will reduce your cost of flue gas scrubbing, if you have a boiler that can accommodate a flue gas desulfurizer.

Mr. **Fuqua**. Do you see that coal cleaning might supplant flue gas scrubbing in the future?

Dr. **Green**. Not by itself.

Mr. **Fuqua**. Can it be used as an environmental protection measure?

Dr. **Green**. Yes. By using better or middle grades of coal, coal cleaning, with some additional moderate measures can serve, I think, to bypass the need for flue gas desulfurization.

Mr. **Fuqua**. Dr. Jefferies, you were talking about the rules or procedures, I guess, whereby we would allocate research funds in a different fashion maybe than we do today. Wouldn't that require a change in the Government procurement regulations to accomplish that?

Mr. **Fuqua**. Then you would suggest we change the regulations in order to accomplish the application of the rules you were talking about, the rules of thumb?

Dr. **Jefferies**. I believe that Government funded research and development should be performed in industry, where that industry has a willingness to commercialize the technology, and regulations or rules that prevent that—and, I'm not clear on the ones you are specifically referring to—should be changed to make that an option for the Government.

Mr. **Fuqua**. We are concerned with such things as proprietary research, patent rights and other——

Dr. **Jefferies**. Oh, I see. As I understand it, the patent restrictions that were applied by the Government were put in place to address the equity question I referred to earlier. In other words, when the Government did choose to fund research and development in industry, Government retention of patent rights made for a more equitable situation.

I really go back to what I said earlier. There certainly is a tradeoff that has to be made between the equity of a situation in which the Government funds industry and the benefit to be derived from it. If you come out in favor of believing that government funded research and development should be performed in industry, then facilitating that through changes in the rules and regulations is certainly an appropriate thing to do.

Mr. **Fuqua**. Of course, we have passed from this committee a patent bill that modifies to some extent and tries to clarify that provision as it relates to proprietary rights. It is still in the Judiciary Committee and has not been acted on to my knowledge until this time. We do try to correct that problem in our legislation.

Dr. Kolb, a large amount of Federal funds have been expended over the years in scientific areas, including the nuclear area and materials research, for high temperatures and reliable components such as you talked about, and you note a wide dispersal of the scientific work. You also note that after all this time and expenditure we are just learning questions but we are a long way from the answer.

What I am really asking is, is our method of allocating and managing these resources to NSF and DOE and the other agencies the most effective means of achieving our objectives, or should we be considering a different approach?

Dr. **Kolb**. My impression is that as DOE was originally conceived, its research effort was split between basic energy sciences, which has a fairly healthy materials component, a new Fossil Energy Division with a materials component, and for a while there was a large conservation program with a materials component. It seemed initially that both the ERDA and DOE program management, and in many cases, material scientists in the National Laboratories, unwisely assumed that the detailed and in many cases outstanding work that had been done in support of nuclear energy programs could be mapped into the fossil energy programs or into the conservation programs without much trouble.

Well, it turns out that materials fail in fossil fuel combustors in ways that are very often quite different, both different reasons and methods of failure, from nuclear reactors and components. So when I say it took a while to learn what questions to ask, I think that materials research that you have identified is a particularly pertinent example.

We had a lot of expertise in nuclear related material; and we had a lot of good workers. But they weren't necessarily prepared to make a quick and easy contribution to fossil energy materials programs. In the intervening 5 or 6 years, I think it is true that a number of researchers at national laboratories, including Oak Ridge and Argonne, as well as industrial researchers at Westinghouse and General Electric, and nonprofit workers at Battelle and several university groups, have all now converged on some of the key fossil energy problems and there has been some very gratifying advances just in the last two or three years.

Now, we see that much of that work has been terminated, or faces termination at the end of this fiscal year, and I do worry about whether or not we will lose the expertise that has been won with some trouble by not having a directed program in that area.

Mr. **Fuqua**. Dr. Green, what are some of the primary areas of coal science that require attention, in your opinion?

Dr. **Green**. Well, chemistry, which has been mentioned earlier by Dr. Solomon and Dr. Kolb. There is the fluid dynamics of high temperature gases with particulates mixed in. The modeling of the flow fields of hot heterogeneous mixtures is beyond the state-of-the-art, especially when the coal particles are pyrolyzing while they are flowing. It will be quite a few years before we can model the realistic situation.

I think both experiments with small-scale systems and mathematical modeling are greatly needed. For example, I have been firing a combustor flowing in a vortex. Some astrophysicists and statistical physicists have been helping me develop a model for this flow field. Believe me, our problem is well beyond the state-of-the-art, for fluid dynamicists and astrophysicists and other applied physicists. So this is a field that is going to take time to evolve. We should give attention to small programs and be careful not to let the big programs be funded at the expense of small programs. This is the same problem we have in particle physics and nuclear physics, where very often to maintain those big accelerators we turn off hundreds of small programs. This is the problem of big science versus little science.

As I assess the state of our understanding of fossil fuel combustion, particularly coal combustion, we have a long row to hoe before we achieve a fundamental understanding. It would be best to let excellence and understanding pop up where it may rather than pretend we can program it.

Mr. **Fuqua**. Dr. Jefferies, would you care to comment?

Dr. **Jefferies**. I believe that the scientific community would benefit from further understanding the fundamentals of coal cleanup, the burning of coal, and the environmental effects of burning coal.

Mr. **Fuqua**. Dr. Kolb?

Dr. **Kolb**. I have to agree with both Dr. Green and Dr. Jefferies. I testified earlier in terms of detailed fields which require support. For example, combustion kinetics and fluid dynamics, which Dr. Green just mentioned, tell us what goes on in the actual burning process itself. Pollutant formation and removal, which starts when you first put the coal into the system and goes on until it finally escapes out the stack, thus giving us opportunities to intervene through that whole process to remove noxious and medically or environmentally-worrisome compounds, is a very fruitful area for research.

An area which hasn't been mentioned is trace species chemistry and recovery. We worry about trace species from an environmental point of view, but there is also some very valuable materials in coal. Many metallic materials that are in short supply and are crucial to defense and industrial production might be removed and economically recovered.

Combustion-induced corrosion and fouling, is another key concern. It does us no good to understand the process if we can't build a plant that will stand there for 20 or 30 years and provide the heat or electricity which we need. That is indeed one of the major reasons why the utilities and the large industrial users of coal have not made further advances in terms of actual use. To do that, you need the advanced materials design and testing work to continue, which you have already asked about.

Finally, I believe it was Dr. Solomon who made the point that coal is a very heterogeneous material in the sense that coal from one mine to another, or even one portion of a seam to another, can be quite different. That means, to burn the coal efficiently and safely, we are going to have to be constantly monitoring coal burners, just as we constantly monitor our nuclear reactors, and fine tuning the controls to allow safe and clean combustion. So far we have made great progress in advanced diagnostics to understand some of the basic physics and chemistry of coal combustion, and we have great opportunities to apply those diagnostics and turn them into "eyes" for a control system, just as some automobiles now have sensors that sense the combustion mixture and automatically adjust it as you change the demand on the drive train of your car. We will need similar systems which monitor the incoming coal, monitor the combustion process, and fine tune that, along with the cleanup process, so that we have an efficient and safe plant that is being adjusted in real time.

Finally, mathematical modeling in general, highlighted again by Dr. Green; none of these systems can evolve from a basic understanding through the pilot plant stage into actual field systems without a great deal of sophisticated mathematical and computer modeling. This allows us to scale from the bench, to the pilot, to the demonstration, and finally to commercial units.

All of those areas I feel are very fruitful areas of research with very high payoffs.

Mr. FUQUA. With the large numbers of coal in the United States and variations between the individual seams in a given reason, is it practical to establish a coal sample bank?

Dr. GREEN. I think it is. As you know, this is a recommendation of the American Physical Society's study on coal utilization. I might say in one of our proposed methods of utilizing coal, we would use a two stage system, in which we attempt to get out most of the ash in the first stage. Here you use enough natural gas to help burn the coal. This would make the system less sensitive to coal variations. Just as an illustration, if you have a low-BTU coal, you incorporate a little more natural gas, a higher grade fuel with the burning coal.

Thus I think coal variability is not an insuperable problem. Currently most coal plants are designed for a narrow range of coals.

Mr. FUQUA. Thank you very much. I thank all of you for being here and sharing with us your thoughts.

[Whereupon, at 3:45 p.m., the subcommittee was adjourned.]

COAL RESEARCH

MONDAY, JUNE 21, 1982

House of Representatives,
Committee on Science and Technology,
Subcommittee on Energy Development and Applications,
Washington, D.C.

The subcommittee met, pursuant to call, at 10 a.m., in the Pittsburgh Energy Technology Center, Bruceton, Pa., Hon. Doug Walgren presiding.

Mr. Walgren. Let me welcome you to the hearings of the Subcommittee on Energy Development and Applications of the Committee on Science and Technology of the House of Representatives.

I want to apologize for the delayed start of this hearing, but transportation is a system beyond control. I do appreciate your being here, and we look forward to the testimony in developing a record here today that we hope will add a constructive element to the judgments that are made about research in coal, and where this country is going with respect to its domestic energy independence.

I cannot help but say at the outset that I personally and many others in the Congress are dismayed at what is happening with the research budgets of the Federal Government, in the coal area in particular. We are talking about a reduction by the Reagan administration from 1981 funding levels in coal research of almost $9 of every $10. This Government had a commitment in 1981 of $1 billion, and that is proposed to fall in the 1983 Reagan budget to $100 million nationwide for research in coal.

I know that in the Pittsburgh area the combination of industry and resources in coal appreciate very much the role that coal has to play, if this country is to have a strong economy in the future. We have a great deal of work to do on the national level, to keep our balance in this area, and I appreciate very much your participating in this hearing. We can take a very good, knowledgeable, and expert record back to work with other Members of Congress who essentially must support effort in this area, if it is to continue.

With that as a personal opening, I would like to yield to my colleague on the Science and Technology Committee, Allen Ertel, who also, as you know, comes from Pennsylvania, from the Harrisburg area. I want to say how much Allen is valued on the Science and Technology Committee in particular. We are sorry that he is running for the governorship of the State of Pennsylvania from the congressional standpoint, because we are going to lose him. He has made a greater contribution than almost any other member of our committee. Allen, you are going to be sorely missed a year from now, but perhaps you will be in a position to be of even greater help to the country as the Chief Executive of the State of Pennsylvania. Allen.

Mr. **Ertel**. Thank you very much, Doug, for those kind words. Doug minimizes his efforts on the Science, Research and Technology Committee because he is the chairman of the committee and has done an outstanding job since he has taken it over last year.

I would like to point out that the cutbacks in the Federal research and development in the coal industry, in the coalfields, and specifically all of the fossil fuels, will have a very devastating effect for the long run, not only for the Nation but for Pennsylvania as well. With high-sulfur coal here, it is incumbent upon us to find ways to utilize that coal in a meaningful way.

Coal is probably one of the most underutilized resources the United States has at the present time. With the cutbacks in the research and development budget, we can anticipate that the low-sulfur coals from the West and even the South will become primary energy sources over Pennsylvania. With no means for Pennsylvania to pick up the slack at the present time, there is no coal policy in Pennsylvania.

We look to see without change a devastation of the coalfields in Pennsylvania. That devastation is already taking place, so that Pennsylvania has a very decided interest in seeing that the research and development budget of the United States is increased for coal development. I am looking forward very much to these hearings, and hopefully as a result of the record we make here, we may be able to convince the national administration to reverse some of its policies. If we cannot convince the national administration to reverse its policies, it is possible that the Congress itself will reverse the policies for the national administration itself.

So we are looking forward to having your testimony and to developing a full and adequate record from which we can argue the position of coal as a primary energy development source for Pennsylvania and for the Nation.

Thank you very much, Doug.

Mr. **Walgren**. The hearing today is the second in a series of hearings on coal research. Last month, in the first session, we had testimony from a very large university, a national laboratory, and from industry, and today we look forward to receiving truly expert testimony from those who have been involved in coal research in the Department of Energy, and also coal-related industries at the Department of Interior and several of the Pittsburgh-based universities and nonprofit research groups.

I want to particularly express the committee's pleasure for the help of Dr. Sun Chun who, as you all know, is the director of the Pittsburgh Energy Technology Center. His assistance that he has given to the committee has been truly invaluable.

There would be no better place to discuss the role of coal in America's overall energy use than at this center, and this center has developed rapidly over the last 5 years to be the Nation's leader in this area. And Dr. Sun Chun's role in that activity is really critical.

So we do appreciate the attention that you have given to the committee, and this institution I think truly represents the clear value to the American taxpayer of the kind of things that we want to do for the country in this area. So we do appreciate the hospitality of the technology center.

[The prepared statement of Hon. John Murtha follows:]

STATEMENT OF HON. JOHN MURTHA

Mr. Chairman, thank you for holding this important hearing. The subject and the place are mutually significant. I have greatly enjoyed working with you on the subject of coal, both as it applies to our Commonwealth and to the Nation. Your Committee on Science and Technology has shown commendable foresight in your past activities and in this review of coal research. In our Appropriations Committee we look to your Committee for guidance as we weigh priorities among many requests for money. Your authorizations have always provided the caliber and extent of help which we seek.

I think it is very appropriate at this time to share with you a deep concern. In the past fifteen years our Nation has been repeatedly subjected to significant changes and impacts. Our growing environmental awareness prompted stringent air quality standards. We have seen oil imports fluctuate in quantity and escalate in price, and suddenly we had to stand in line for gasoline. We have seen Americans held hostage by an oil-supplying nation, questioning our national sovereignty and future safety. We see the Middle East, a primary oil source, threatened by communistic encroachment as Afghanistan was occupied. All these actions give us a sense of grave insecurity.

At the same time, ths nation has been endowed with an energy resource far in excess of our foreign oil supplies. The 12th District of Pennsylvania has recoverable coal reserves which have an oil energy equivalent of 33 billion barrels, which is more than the oil in Iraq, or more than all the oil in South America. It therefore is difficult to justify the expenditure of huge sums of money for the armed forces in the name of national defense unless those expenditures include coal research and development. The maintenance of a secure oil supply line from the Near East will be extremely expensive. What better way can we spend some of those funds than to eliminate the need of those foreign energy sources? Only when we know how to burn all ranks of coal cleanly and efficiently, to convert coal to gases and liquids, to extract coal at minimal hazard, and to protect our health and environment, only then can we maintain the amount of control we have enjoyed in the past. This knowledge will come from efforts at this Energy Technology Center, from the University of Pittsburgh, Penn State University, and Western Pennsylvania coal conservation pilot plants, to name a few sources. Only then we can expect increased employment, enhanced technical skills, improved balance of payments, and an improved feeling of national security. Benefits can be expected in our local labor force and our colleges and universities. To have such an important energy supply and to lack basic knowledge of that supply seems foolish and impossible to explain.

Mr. Chairman, thank you for this opportunity to express my views and to encourage you in this important series of hearings. I look forward to the benefits we will all obtain from your efforts.

Mr. WALGREN. The first panel, if I could invite you folks to come forward again, Dr. Sun Chun, the director of the Pittsburgh Energy Technology Center, accompanied by Dr. Joseph Ray, who is the director of research with Battelle Memorial Institute; John Sudbury, vice president of the Coal Research Division of Conoco; and Dr. Max Williams, who is the dean of the School of Engineering of the University of Pittsburgh.

Gentlemen, if you would come forward, we appreciate very much your participating in these hearings. Written statements will certainly be made part of the record, and you may feel free to supplement any statements that you wish to submit today with any other reactions that you might have from hearing other witnesses, or points that you feel need to be made.

In the interest of time, depending on the length of your written statement, you are certainly invited to summarize or outline or communicate in whatever way you feel is most effective, and so, with that, let me ask first, Dr. Sun Chun, if you would proceed.

STATEMENTS OF DR. SUN CHUN, DIRECTOR, PITTSBURGH ENERGY TECHNOLOGY CENTER, PITTSBURGH, PA.; DR. JOSEPH W. RAY, DIRECTOR OF RESEARCH, BATTELLE MEMORIAL INSTITUTE, COLUMBUS, OHIO; JOHN D. SUDBURY, VICE PRESIDENT, COAL RESEARCH DIVISION, CONOCO, INC., LIBRARY, PA.; AND DR. MAX L. WILLIAMS, DEAN, SCHOOL OF ENGINEERING, UNIVERSITY OF PITTSBURGH, PITTSBURGH, PA.

Dr. CHUN. Thank you, Mr. Chairman and members of the committee. My name is Sun Chun and, as the director of the Pittsburgh Energy Technology Center, I would like to welcome you to Pittsburgh and to the Bruceton Research Center. Allow me to begin by expressing my appreciation for giving me the opportunity to discuss the fossil energy program in coal technology underway at PETC.

As some of you may already know, PETC has been a leader in the fields of coal science and technology for well over 30 years. This research station has actually been operating since 1910, beginning as an experimental coal mine and coal analysis laboratory in the U.S. Bureau of Mines. When the Synthetic Liquid Fuels Act was implemented in 1945, PETC's direction in coal science began on a new course of conducting research on converting coal into synthetic liquid fuels. By continuing the research work begun in Germany during the war years, scientists at Bruceton developed successful methods of producing liquid fuels from American coals.

However, the discovery of abundant oil, both in the United States and in the Middle East, diminished the interest in coal research. To help renew this much-needed interest, the Office of Coal Research (OCR) was created in 1961 within the U.S. Department of the Interior to manage contract research in coal technology.

The Bruceton Laboratories, under the direction of the Bureau of Mines, became the Pittsburgh Energy Research Center (PERC) and was responsible for conducting the Federal Government's in-house coal research effort. During this time, the center's activities expanded to include testing in coal and synthetic fuel combustion and characterization. In 1975, PERC was transferred to the newly created Energy Research and Development Administration (ERDA), and in 1977 to the Department of Energy where we were given the name Pittsburgh Energy Technology Center (PETC).

In the past decade, our mission has been oriented toward promoting those technologies that will enhance the growth of the synthetic fuels industry in the United States. Presently, PETC is the largest of the Department of Energy's five technology centers in the fossil energy program, with 328 full-time employees. We maintain the distinction of being DOE's lead laboratory in coal liquefaction, combustion phenomena, coal preparation, and alternative fuels combustion.

Since the inception of the Department of Energy, we have not only conducted the in-house laboratory research and development in these areas, but we have also managed the nationwide DOE contracts in the private sector that pertain to these fields.

In fiscal year 1982, PETC is operating its in-house R&D on a budget of approximately $13.3 million. Furthermore, our active programmatic contracts amount to a total worth of approximately $300.5 million. The review and selection process for awarding these contracts is administered here at PETC within the terms of authority delegated to us.

The fuel combustion testing at PETC has successfully demonstrated that our Nation's petroleum supply can be extended by mixing finely ground coal with oil and burning such a mixture in boilers designed to burn oil. After this program was completed, the private sector began experimenting with the technology. In fact, a 3-year economic survey by the Electric Power Research Institute (EPRI) published just last month, found that coal-oil mixtures can save up to 15 percent on fuel costs in utility and industrial applications.

More recently, PETC has been conducting in-house research activities in burning mixtures of coal and water in these same large-scale applications. The potential impact of this technology is far greater than that of coal-oil mixtures due to the fact that we can use two abundant resources that are indigenous to the United States—coal and water—to effectively replace 40 to 60 percent of the oil burned by American industry with coal.

The EPRI study that I referred to a moment ago also pointed out that, although coal-oil mixtures result in a savings, industry is eagerly waiting for coal-water mixture technology to be successfully demonstrated so that the significant benefits in fuel savings can be felt throughout this sector of our economy. The coal-water mixture testing at PETC is nearing the "proof-of-concept" stage and we will have fully completed this project within the next 2 years.

Ultimately, we hope to have provided enough technical data for private industry to adopt coal-water mixture technology by the mid-1980's.

It would be irresponsible if a Government coal laboratory did not consider the environmental implications of coal utilization. With this in mind, PETC has conducted over a decade of extensive research with the purpose of identifying the most effective means of removing pollutants that result from the burning of coal.

We have taken two basic approaches to meet this end. The first method is through coal preparation, by which the impurities in coal are removed both physically and chemically prior to combustion of the fuel. Numerous coal preparation techniques are being developed at PETC whereby over 90 percent of the sulfur and ash found in raw coal can be removed.

The other environmental control technology is generically referred to as flue gas desulfurization. In this technique, sulfur in the combustion effluent from an industrial or utility coal-fired boiler can be removed in any number of ways.

In-house research at PETC has enhanced the prospects for such methods as the baghouse filter, spray dryer flue gas desulfurization, and the copper oxide process for simultaneous sulfur dioxide and nitrogen oxide removal. Flue gas desulfurization and coal preparation are two technologies that complement each other extremely well. Surely, their significance in helping the industrial sector comply with environmental regulations will have a direct bearing on the increasing use of coal as an energy source.

The research in analytical chemistry at PETC is conducted in a truly remarkable building that is designed with the sole purpose of analyzing and characterizing coals and coal-derived liquids. This facility houses one of the most diverse, yet comprehensive, ranges of analytical instrumentation in the United States, if not the world.

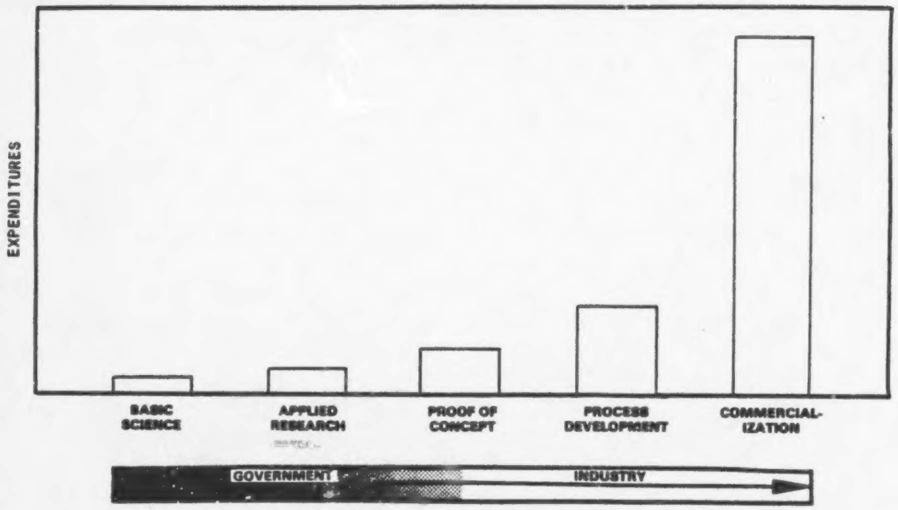
Our analytical chemistry capability has made PETC the Federal Government's only referee laboratory in coal analysis since the Bruceton Research Center was founded in 1910. This function is designed to protect the interests of the Government as a buyer of large quantities of coal and to provide the analytical information required to map out U.S. coal reserves.

In addition, we perform thousands of coal analyses each year for such agencies as the Department of Defense and the Department of the Interior, as well as the Department of Energy.

These are just a few of the more recent achievements in coal science that have taken place here. PETC also has a program plan for the future that conforms to the R&D policy of the Department of Energy.

As you all know, DOE is focusing on those technologies that are considered to be a high-investment risk for the private sector but have significant potential benefits in the long term.

[The graph attached to Dr. Chun's statement follows:]



Dr. CHUN. This is to say that the direct Federal role in technology development extends to the "proof-of-concept" stage. The development of the technology to commercial scale should be left to the private sector.

The research at PETC always has been, and will continue to be, aimed at performing long-range technologies that are needed to help bring about a viable synthetic fuels industry. In the area of liquefaction, we will be investigating the technical practicality of such direct liquefaction technologies as integrated two-stage liquefaction, which could lower production costs while increasing the thermal efficiency of the process.

Our indirect liquefaction research is beginning to look at the liquid-phase methanol process, which offers many opportunities in itself while, at the same time, will help us to better understand other liquefaction reactions. This knowledge will be integrated into a comprehensive and current data base in coal liquefaction located at PETC, which is constantly growing to meet the needs of industry.

In coal preparation, we are studying the effectiveness of burning a pelletized, low-grade lignite that has been upgraded to a higher heat content but lower sulfur content. We feel that the economic benefits of such a product could be tremendous since lignite is cheap, easily mined, and pelletizing would reduce its handling costs. We are also looking into new and innovative methods for the physical and chemical cleaning of pulverized coals by capitalizing on the inherent differences between coal and its impurities, such as magnetic susceptibility and specific gravity.

I have already mentioned our coal-water mixture research. In addition to that, we will continue to look at burning coal mixed with other liquids. One particular mixture that we think will prove to be successful is a coal-methanol mixture.

The benefits of this technology have the potential of surpassing those of coal-water mixtures in that even less retrofitting and modifications of the existing boiler may be required. We are optimistic that a breakthrough in coal-methanol mixture technology for displacing oil in industrial and utility applications would result in a significant impact on the demand for imported oil.

These examples, I hope, have highlighted the more outstanding achievements that have taken place here in recent years. There are countless others, less significant by comparison, but collectively they have helped accelerate the significant advances made in coal utilization technology over the past 50 years.

But such achievements do not occur by themselves; people make them happen. The scientists and researchers at PETC have earned worldwide reputations as being leaders in the field of coal science. Their dedication and hard work are what transforms a group of laboratory buildings into an efficient and effective arm of the Nation's coal R&D effort.

The key to a successful R&D program is the transfer of technology from the public to the private sector of our economy. Throughout the 1960's and 1970's, and still today, PETC has been the Federal Government's largest laboratory in the area of coal liquefaction. Much of the knowledge and technical information that has been applied toward the development of a synfuels industry has been gleaned from the fundamental and engineering research performed in these laboratories. The information required to construct many of the Nation's experimental synthetic fuel facilities during the 1970's was information based, in large part, on the work of Government researchers at PETC.

As private industry begins to move advanced coal technologies into commercial practices, PETC will continue to make available the wealth of knowledge and expertise obtained from our in-house and contracted research. This will enable sound investment decisions to be made relevant to the continued development and commercialization of the most promising technologies.

In addition, we will continue to explore new high-risk concepts in coal technology that industry is unable to pursue on its own. This two-pronged effort has been the fundamental mission at PETC since its inception, and will continue in the years ahead as an essential function of the Federal Government's program on fossil energy R&D.

As you pointed out in your letter of invitation, Mr. Chairman, the emphasis of the fossil energy program has been refocused. Budget and personnel considerations, and the fundamental restructuring of the Federal role in energy development, have combined to change the character of work at PETC.

As I have described, the departmental policy now stresses fundamental research and development of high-risk, potentially high-payoff fossil fuel concepts, rather than support of large-scale, near-commercial technologies. As the national energy program continues the transition to a greater reliance on market forces to set the pace of new technology development, we anticipate that the scope of work at PETC will likewise continue to change.

Therefore, in our planning for fiscal year 1983 and beyond, we are exploring alternatives that will maintain the current momentum of technological improvement while continuing the shift of R&D responsibility to the private sector and reducing Federal budget and manpower requirements.

In this regard, we are examining new management strategies to increase the efficiency of our research activities. We are also evaluating current in-house research programs, projects and other activities to determine those that could effectively be conducted under outside contract in future years.

Although final decisions are contingent upon congressional action on the administration's current budget proposals, we at PETC remain committed to insuring that our coal technology R&D program is properly balanced between Federal, industrial, and academic institutions and continues to play an effective role in the Nation's energy future.

Thank you, Mr. Chairman.

[The prepared statement of Dr. Chun follows:]

STATEMENT OF DR. SUN W. CHUN, DIRECTOR, PITTSBURGH ENERGY TECHNOLOGY CENTER, U.S. DEPARTMENT OF ENERGY

Mr. Chairman and Members of the Committee:

As the Director of the Pittsburgh Energy Technology Center, I'd like to welcome you to Pittsburgh and to the Bruceton Research Center. Allow me to begin by expressing my appreciation for giving me the opportunity to discuss the Fossil Energy Program in Coal Technology underway at PETC. As some of you may already know, PETC has been a leader in the fields of coal science and technology for well over 30 years. This research station has actually been operating since 1910, beginning as an experimental coal mine and coal analysis laboratory in the U.S. Bureau of Mines. When the Synthetic Liquid Fuels Act was implemented in 1945, PETC's direction in coal science began on a new course of conducting research in converting coal into synthetic liquid fuels. By continuing the research work begun in Germany during the war years, scientists at Bruceton developed successful methods of producing liquid fuels from American coals.

However, the discovery of abundant oil both in the United States and in the Middle East diminished the interest in coal research. To help renew this much needed interest, the Office of Coal Research (OCR) was created in 1961 within the U.S. Department of the Interior to manage contract research in coal technology. The Bruceton Laboratories, under the direction of the Bureau of Mines, became the Pittsburgh Energy Research Center (PERC) and was responsible for conducting the Federal Government's in-house coal research effort. During this time, the Center's activities expanded to include testing in coal and synthetic fuel combustion, and characterization. In 1975, PERC was transferred to the newly created Energy Research and Development Administration (ERDA), and in 1977 to the Department of Energy where we were given the name Pittsburgh Energy Technology Center (PETC).

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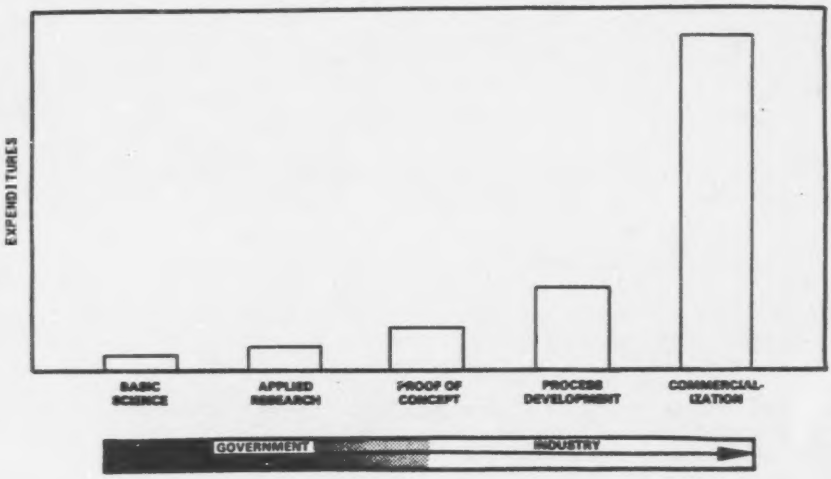

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As private industry begins to move advanced coal technologies into commercial practice, PETC will continue to make available the wealth of knowledge and expertise obtained from our in-house and contracted research. This will enable sound investment decisions to be made relevant to the continued development and commercialization of the most promising technologies. In addition, we will continue to explore new high-risk concepts in coal technology that industry is unable to pursue on its own. This two-pronged effort has been the fundamental mission at PETC since its inception, and will continue in the years ahead as an essential function of the Federal Government's program in Fossil Energy R&D.

As you pointed out in your letter of invitation, Mr. Chairman, the emphasis of the Fossil Energy program has been refocused. Budget and personnel considerations, and the fundamental restructuring of the Federal role in energy development, have combined to change the character of work at PETC. As I have described, the Departmental policy now stresses fundamental research and development of high-risk, potentially high-payoff fossil fuel concepts, rather than support of large-scale, near-commercial technologies. As the national energy program continues the transition to a greater reliance on market forces to set the pace of new technology development, we anticipate that the scope of work at PETC will likewise continue to change.

Therefore, in our planning for FY 1983 and beyond, we are exploring alternatives that will maintain the current momentum of technological improvement while continuing the shift of R&D responsibility to the private sector and reducing Federal budget and manpower requirements. In this regard, we are examining new management strategies to increase the efficiency of our research activities. We are also evaluating current in-house research programs, projects and other activities to determine those that could effectively be conducted under outside contract in future years. Although final decisions are contingent upon Congressional action on the Administration's current budget proposals, we at PETC remain committed to ensuring that our coal technology R&D program is properly balanced between Federal, industrial, and academic institutions and continues to play an effective role in the Nation's energy future.

Thank you, Mr. Chairman, I will be most happy to entertain any questions from you or from members of the Committee.

Department of Energy
Pittsburgh Energy Technology Center
P.O. Box 10940
Pittsburgh, Pennsylvania 15236

BIOGRAPHICAL SKETCH OF SUN W. CHUN

Dr. Sun W. Chun is the Director of the Pittsburgh Energy Technology Center (PETC), the Department of Energy's (DOE) leading laboratory in coal mining, preparation, liquefaction, combustion and utilization research.

As Director, Dr. Chun manages PETC's in-house research and national research and development programs in coal mining, coal preparation, coal liquefaction, alternative-fuel combustion, mining, coal science and supporting technologies. He directs approximately 400 engineers, scientists, chemists, program managers, and support personnel at the center and is responsible for a budget of approximately $150 million. Research at PETC has already produced significant near- and long-term alternatives to dwindling energy reserves.

Prior to his present position, Dr. Chun was Deputy Director of PETC for two years. He has also managed the center's Process Sciences Division, where he directed chemistry, catalysis, process development, pyrolysis, and coal structure programs.

Before coming to PETC, Dr. Chun held various management positions with the Gulf Research and Development Company, and while there supervised and conducted research in catalytic coal liquids process technology, hydrocarbon processing, and exploratory research. He participated in a management training program during his last five years at Gulf and completed DOE's 2-year Executive Development Program in 1979.

Dr. Chun is a member of the American Institute of Chemical Engineers, Sigma Xi, American Chemical Society and American Management Association. He is an active member of the policy committee of the Pittsburgh Federal Executive Board. Dr. Chun has over 20 patents and numerous publications in refining and synthetic fuels to his credit.

Dr. Chun received his B.Ch.E., M.S., and Ph.D. degrees in Chemical Engineering from Ohio State University. In May, 1981, he received the 1981 Benjamin G. Lamme Award from Ohio State University, the highest honor from the College of Engineering, for outstanding service. He has also attended the Federal Executive Institute at Charlottesville, Virginia.

He represented the United States at the 1981 International Coal Science Conference in Dusseldorf, West Germany as the head delegate and was elected as the President of the International Energy Agency's 1983 International Coal Science Conference to be held in the United States.

Dr. Chun, his wife, Inmook, and their two children, Felicia and Edward, reside in Murraysville, Pennsylvania.

May 1982

Mr. WALGREN. Thank you very much, Dr. Chun. We, too, want to work with you to make sure that that happens, and we will have a chance to explore some of the details of that when we turn to questioning, but I would like to ask the other members of the panel to get all of the testimony of the folks on the panel before we enter into discussion.

Dr. RAY. Mr. Chairman and members of the Subcommittee on Energy Development and Applications, my name is Joseph W. Ray and I am associate director of Battelle's Columbus division, based in Columbus, Ohio.

Coal technology research and development at Battelle dates back to the beginnings of Battelle Memorial Institute over 50 years ago. The will of Gordon Battelle, which founded our institute as an organization for industrial and government research, specifically mentions coal as a field of endeavor. As a result, our background in this area is long and varied.

I appreciate the opportunity today to share with you some of my observations on achievements and opportunities in coal science and technology. I believe there is a need for a national commitment to coal technology and utilization, with a goal of cost-effective commercialization. My testimony today will illustrate the need for a strong Federal role in support of this goal.

There is no doubt that Federal support for coal research, development, and demonstration during the past decade has resulted in a revitalization of the potential for using coal. During the 1960's, coal research had declined to a relatively low level, with relatively little research under way.

For example, in 1972, Battelle initiated a major, internally supported program in coal research. At the outset of that program, we found that, as a result of more than a decade of limited support for coal research, we experienced great difficulty in locating a sufficient number of experienced scientists and engineers to pursue this program.

I suspect that a number of other organizations had a similar problem in the mid-1970's. Federal and private sector support since that time has provided the impetus for industry and academia to turn their attention to increasing the scientific knowledge base on coal utilization and to demonstrating and commercializing this technology. As a result, the United States once again has the cadre of coal researchers necessary to pursue a national commitment to coal technology development and utilization. We should not let this capability degrade.

What is important, I believe, is a commitment to the future of coal utilization in this country. This can be a key to freeing the United States from dependence on energy imports. Considering the nature of the coal industry today, it is unlikely that the free market will naturally stimulate the development of new process technology for coal conversion.

The risk is often too high and the benefit too frequently accrues to the coal user, not necessarily the coal supplier. What is needed is stability and momentum, which can be strengthened by Federal support of R&D on both innovative process technology and the establishment of sound engineering data bases.

Battelle has much experience in working with industry to commercialize new technology. Solutions to problems come through our response to needs—by developing new technology or by using novel approaches for implementing existing concepts.

For example, in 1973 two of our staff conceived of an improved way of combusting coal in a fluidized bed. This process, which we call multisolid fluidized bed combustion, or MSFBC, was initially proven by Battelle with our own moneys. The ability to scale up the process was made possible with Federal support in the mid-1970's. Today this technology has moved to the commercial stage and Conoco is operating a unit in Texas which burns coal to produce 50,000 lb/hr of steam for enhanced oil recovery.

This unit was built by Struthers' Thermoflood, one of several MSFBC licensees. Again, without Federal support at a critical stage of this development, it is unlikely that this technology could have moved so rapidly to commercialization.

Recently Battelle has been working with the Tennessee Valley Authority [TVA], with support from DOE, to develop relationships between coal characteristics and the performance of over 50 of TVA's powerplants. Fuel-related problems such as pulverizer wear, slagging and fouling and corrosion all affect electrical outages. Relationships developed in this program offer guidelines to the utilities for coal selection and preparation, and these can be used to reduce powerplant outages. Even in conventional areas of coal use, then, we see that there are opportunities to develop improved understandings which can be used to enhance coal use.

I believe it is important that Federal R&D support continue, so as to insure that the lowest cost technology will ultimately find its way into the marketplace. The savings from a properly structured R&D program in future energy costs to the Nation can be substantial. Although I am not prepared today to discuss in any detail what a "properly structured" R&D program should consist of, I believe that some commercial endeavors must result from this program if it is to be judged successful.

It is also clear that these commercial applications should be able to be justified without Government subsidies, once the initial plant is operational at design conditions. My written testimony contains an example which cites three approaches for increasing the transportation fuel supply by coal utilization. Time does not permit me to elaborate, but I would like to make two important points that these examples support.

First, we need a balanced program that leads to both some early payoffs and to a technology base for the long range. Second, we need to look at the transfer of technology to industry.

There is potential for a risk gap between the level of development currently contemplated with limited Federal involvement, and the development level required before industry considers the technology and market risks sufficiently defined to invest in commercialization. This gap must be bridged by industry's early involvement and by Government support beyond the bench scale, although not necessarily to demonstration plants. I believe that the portion of the research and development aimed at commercialization can be executed at relatively modest cost. Also I believe it will save the energy consumer money and provide a strong technology base for development of more advanced coal conversion and utilization technology.

In summary, I encourage the committee to support a strong Federal program in coal research and development. Such a program should stimulate the development of new and underutilized technologies. It should establish a strong engineering data base on coal characteristics, process phenomena, materials of construction, and other fundamental data needed for the future utilization of coal and coal conversion products.

The program should be balanced in scope and participation. It is important to involve academia and independent research and development organizations, and just as important that future industrial users of the technology participate at an early stage.

It is my belief that Federal support is necessary to minimize the risk and accelerate the development of coal conversion technology. What is needed is a broad-based, well-managed program which focuses on high risk R&D and technology transfer.

My thanks to you, Mr. Chairman and to all the members of this subcommittee, for the opportunity to participate in these hearings today.

[The prepared statement of Dr. Ray follows:]

STATEMENT OF DR. JOSEPH W. RAY, ASSOCIATE DIRECTOR, BATTELLE COLUMBUS DIVISION

Mr. Chairman and Members of the Subcommittee on Energy Development and Applications. My name is Joseph Ray and I am Associate Director of Battelle's Columbus Division, based in Columbus, Ohio. It is a pleasure to have the opportunity to testify at this important hearing on coal research.

Coal technology research and development at Battelle dates back to the beginnings of Battelle Memorial Institute over 50 years ago. The Will of Gordon Battelle, which provided for the creation of our Institute as an organization for industrial and government research, specifically mentions coal as a field of endeavor. As a result, our background in this area is long and varied. We pioneered work on the burning characteristics of pulverized coal, and are active in research on metallurgical coke and coke-oven operation. We are heavily involved in the development of technology for coal-tar chemicals, gasification, liquefaction, turbine studies, flame stabilization, coal cleaning, carbonization, equipment design, coal characterization, pollution control, coal-mining equipment, and process design and economics. Battelle took an active part in the formation of Bituminuous Coal Research, Inc. in 1933 and conducted most of its research until 1950 when BCR established its own research laboratory.

As you can see, the utilization of coal is an important area of R&D for Battelle. I appreciate the opportunity today to share with you some of my observations on achievements and opportunities in coal science and technology. I believe there is a need for a national commitment to coal technology and utilization, with a goal of early, cost-effective commercialization. My testimony today will illustrate the need for a strong federal role in support of this goal.

There is no doubt that Federal support for coal research and development during the past decade has resulted in a revitalization of the potential for using coal. During the 1960's, coal research had declined to a minimal level, with practically no academic research under way. In 1972, Battelle initiated a major, internally supported program in coal research. At the outset of that program, we found that, as a result of more than a decade of limited Federal support for coal research, we experienced great difficulty in locating a sufficient number of experienced scientists and engineers to pursue this program. I suspect that a number of other organizations had a similar problems in the mid-1970's. Federal and private sector support since that time has provided the impetus for industry and academia to turn their attention to increasing the scientific knowledge base on coal utilization and to demonstrating and commercializing this technology. As a result, the United States once again has the cadre of coal researchers necessary to pursue a national commitment to coal technology development and utilization. We should not let this capability degrade.

What is important, I believe, is a commitment to the future of coal utilization in this country. This will be the key to freeing the United States from dependence on energy imports. Considering the nature of the coal industry today, it is unlikely that the free market will naturally stimulate the development of new process technology for coal conversion. The risk is often too high and the benefit too frequently accrues to the coal user, not the coal supplier. What is needed is stability and momentum, such as can be provided by the Federal government through its support of R&D on both innovative process technology and the establishment of sound engineering data bases.

There are significant improvements in coal conversion yet to be developed and implemented. For example, work conducted by Battelle for the Department of Energy on catalytic gasification of coal has shown much promise, not only for producing both a fuel gas and a spectrum of chemical products, but also for environmentally acceptable combustion of coal. When coal is treated with an inexpensive material such as calcium, sulfur is captured during combustion of the pulverized coal. The understandings developed in this Federally-sponsored R&D program provide a strong technical base which can be used in the development of future gasification and combustion processes. This technology appears economically attractive and we believe its development would not have been possible without Federal support.

Battelle has much experience in working with industry to commercialize new technology. Solutions to problems come through our response to a need or by using novel approaches for implementing existing concepts. For example, in 1973 two of our staff conceived of an improved way of combusting coal in a fluidized bed. This process, which we call multisolid fluidized bed combustion (MSFBC), was initially proven by Battelle with our own monies. The ability to scale up the process was made possible with Federal support in the mid-1970's. Today, this technology has moved to the commercial stage and CONOCO is operating a unit in Texas which burns coal to produce 50,000 lb/hr of steam for enhanced oil recovery. This unit was built by Struther's Thermoflood, one of several MSFBC licensees. Again, without Federal support at a critical stage of this development, it is unlikely that this technology could have moved so rapidly to commercialization.

Recently Battelle has been working with the Tennessee Valley Authority (TVA), with support from DOE, to develop relationships between coal characteristics and the performance of over 50 of TVA's power plants. Fuel-related problems such as pulverizer wear, slagging and fouling and corrosion all affect electrical outages. Relationships developed in this program offer guidelines to the utilities for coal selection and preparation, and these can be used to reduce power plant outages. This example shows that even in conventional areas of coal use, opportunities exist to develop improved understandings which can be used to enhance coal use.

It is very important that advanced technology be developed to the point where it can be fully evaluated. Several years ago Battelle developed a chemical coal cleaning process which was technically sound but economically unattractive at the time. Recently, there has been substantial industrial interest in this process technology for upgrading low-rank coals and removing the sulfur and ash from Eastern coals. The difference today is not the technology but the price of oil, which is equivalent to over $150/ton for a cleaned coal. Industrial use of slurries of deep-cleaned coal and water appear to be an economical substitute for oil in boilers. What is important is that the technology has been advanced and was developed to a point where it can be picked up in the future. It is not always possible to determine the ultimate value of R&D, but without Federal support, it is unlikely that sufficient new technology will be available in the near or long-term future.

I believe it is important that Federal R&D support continue to ensure that the lowest cost technology will ultimately find its way into the marketplace. The savings from a properly structured R&D program in future energy costs to the nation can be substantial. Although I am not prepared today to discuss in any detail what a "properly structured" R&D program should consist of, I believe that some commercial endeavors must result from this program if it is to be judged successful. It is also clear that these commercial applications should be able to be justified economically without government subsidies, once the initial plant is operational at design conditions. For example, if we assume that a national goal is to increase the transportation fuel supply by coal utilization, this could be accomplished via the three basic approaches listed below.

- DISPLACEMENT

  COAL → MEDIUM BTU GAS → PETROLEUM → MOTOR FUEL/HEATING OIL

- DIRECT PRODUCTION

  COAL → COAL LIQUIDS → MOTOR FUEL/HEATING OIL

  COAL → SYNGAS → MOTOR FUEL

- SUBSTITUTION

  COAL → SYNTHETIC NATURAL GAS → SYNTHETIC NATURAL GAS FUELED AUTOS

  COAL → SYNTHETIC NATURAL GAS → HEATING OIL

The first approach, displacement, utilizes coal to produce a medium-Btu gas and substitutes the medium-Btu gas for petroleum in, for example, a fuel-oil burning electric utility. This unutilized fuel oil will then induce a shift in the refinery product slate to increase gasoline production. The limitation of this approach is that it does not increase total oil supply but rather substitutes coal, in the form of a medium Btu gas, for fuel oil. However, a rough calculation indicates that this approach could release petroleum products for transportation utilization equivalent some twenty to thirty 50,000 barrel/day synfuel plants by simply displacing the fuel oil currently used by electric utilities. This would require a much lower capital investment than would be required by the second approach, direct production.

Direct production is attractive because it produces from coal the desired petroleum-based product in a form that fits into the existing energy market. Unfortunately, capital requirements are far higher than can be justified in today's energy and economic climate. Thus, if left to free-market economics, this approach will gradually be implemented as the world oil supply declines. However, early implementation of the first approach will allow time to rethink new and more economic approaches to direct production of synfuels.

The third approach requires substituting a coal-derived fuel for a petroleum-based fuel. For example, if technical, environmental, or economic constraints prevent production of gasoline from coal, synthetic natural gas (or methanol) could be used as a transportation fuel. However, there does not seem to be any cost advantage in this route.

Thus, the approach that is most likely to result in early commercialization is the first one--the displacement approach. Based on our experience, we believe that technology can be developed so coal can be used to displace petroleum in a more cost-effective manner. It appears unlikely that further research on more "conventional" synfuel approaches will result in the magnitude of cost reductions necessary to make them economically feasible. Our long-range technology should therefore focus on areas where significant cost reductions in direct production can be made.

Finally, an extremely critical point should be made regarding the transfer of this technology to industry. This is the risk gap that will exist between the level of development currently contemplated with limited Federal involvement and the development level required before industry considers the technology and market risks sufficiently defined to invest in commercialization. This gap must be bridged by industry's early involvement and by government support beyond the bench-scale (but not necessarily to demonstration plants). I believe that the portion of the research and development aimed at commercialization can be executed at relatively modest cost. I also believe it will save the energy consumer money and provide a strong technology base for developing more advanced coal conversion and utilization technology.

In summary, I encourage the Committee to support a strong Federal program in coal research and development. Such a program should stimulate the development of new and underutilized technologies. It should establish a strong engineering data base on coal characteristics, process phenomena, materials of construction, and other fundamental scientific data needed for the future utilization of coal conversion products. The program should be balanced in scope and participation. It is important to involve academia and independent research and development organizations, and just as important that future industrial users of the technology participate at an early stage. It is my belief that Federal support is necessary to minimize the risk and accelerate the development of coal conversion technology. What is needed is a broad-based, well-managed program which focuses on high risk R&D and technology transfer.

My thanks to you Mr. Chairman and to all the members of this Committee for the opportunity to participate in these hearings today.

Dr. Joseph W. Ray
Associate Director
Battelle Columbus Division

In his post as Associate Director of Battelle-Columbus, Joseph W. Ray currently heads business development and management systems for the Columbus Division. Prior to this assignment, he directed the Division's research activities in the Washington, D.C., area, including work in systems, policy and planning analysis for a number of federal agencies. Earlier in his career, Dr. Ray managed research groups engaged in systems engineering and analysis as well as nuclear power technology.

Dr. Ray holds a Ph.D. in systems analysis from The Ohio State University and an M.S. in nuclear engineering and a B.S. in chemical engineering from the University of Michigan. He is a member of the Society of Sigma Xi, Alpha Pi Mu, the Institute of Management Sciences, and is a Fellow of the Washington, D.C. Academy of Sciences. He is the author or coauthor of over 20 technical reports and publications.

Mr. WALGREN. We appreciate your testimony.

Next is John Sudbury from Conoco. Welcome to the committee.

Mr. SUDBURY. Mr. Chairman, I appreciate the invitation to be here. Thanks from all of us. I will depart from the remarks that I prepared. I think we are all in agreement that coal is a major and an underutilized resource in our country today, technological, political, and economic factors all influencing the rate at which this resource is going to be developed, and certainly as representing one of the major coal companies in the U.S. and in the world, it is our motive to do all that we can do, get all the help that we can get, in supporting the development of coal.

Obviously, the Federal Government has been involved in places like here at Bruceton for a long, long time in coal research, although the massive Federal involvement out of Washington really started about 15 years with the institution of the Office of Coal Research (OCR), ERDA and then DOE. Coal research in my company, as represented over in Library, 2 or 3 miles from here, has been going on since about 1947, under the names of Consol and later Conoco and now we are a part, as you know, of the DuPont Co.

We have carried out significant work there, and in that period we have been active in a large number of federally sponsored programs, both jointly sponsored and totally sponsored by the Federal Government. In fact, the initial OCR program in the creation of the Office of Coal Research was to carry out project for liquefaction over at Cresap, in Moundville, W. Va.

During the last few years we have been a party to a number of projects with the Federal Government and have spent substantially more than $100 million of Federal money and quite a bit more than $100 million of our own money during this period.

The results of these programs, and I cite these because I think they are typical of the examples of all of us, on the positive side, I think, certainly—as has already been suggested on my right by both gentlemen, I believe—there have been really significant advances in technology over the last few years, and certainly there have been a lot of fossil people trained during this period of time, and both of these are resources that we cannot afford to lose.

On the negative side, I think these Government programs that we have been involved in have to date not succeeded in carrying out any significant commercial demonstrations or any things that have really led to real commercial utilization of coal. Large expenditures of money, the efficiency of these expenditures, have not been so good as we have gotten to the very large-scale, very large dollars.

The very nature of the Government control of these projects and Government control goes with Government sponsorship has appeared to make it impossible to make decisions necessary to plan, fund, build, and operate large plants.

For example, we tried a number of times through the years to indicate a real need for more Government support through DOE and ERDA in the steel industry and the power industry. These are things very important to western Pennsylvania. The answer we usually got was, "They are not in our program. Don't bother us with these kinds of proposals." So that I think cited the difficulty of working with ERDA and DOE in selection of projects, planning of projects, and so forth.

Likewise, as we have gotten involved in building larger demonstrations trying to lead to commercial plants, the number of viewpoints that have to be satisfied by Government-owned and operated plants is just too difficult, and none of these has been projects successful. They have all tended to bog down: SRC-1 is almost down the tube, SRC-2, EDS, the slagging projects that we were involved in, H-coal—none of these appears to be moving toward any real commercial reality.

As the financial calls on these projects got great, a side effect of this that really I think hurt a lot of us, and you know these are things that took place before the last presidential election, not since many exploratory-type projects that I think the Government might have been better advised to stay with were canceled, because all the money was being consumed in the rapidly escalating costs of a very large project.

So the result is a major number of the exploratory-type projects were eliminated because funds were lost, and then eventually the large projects went down the tubes, because they just got too large and the incentive to do them decreased too much.

I think we have had to conclude from this that only private industry is going to be able to move quickly when the technology and the economics are OK for these projects, an example in case being Tennessee-Eastman's decision to build a plant to make oxygenated chemicals using coal gasification technology. This project is moving forward essentially on budget and on schedule, and will be an outstanding example of the way a project might be run.

The future role of the Government in coal development, to me, is that we don't need the massive quantities of money. We do need—and again I can agree qualitatively with the commments on the right—we do need Government involvement. We do need Government involvement in supporting innovative concepts, whether they be carried out at universities, at private institutions, places like Battelle or the Bruceton group, and so forth.

There are a lot of good innovative groups, and I think, as we all know, many of the real innovations in this Nation have come from some of the smaller groups, smaller industrial groups, university groups, and so forth.

In my opinion though, and I think the opinion of our corporation, it is just not feasible for the Government to build and own and operate these very large plants. The Government has a role that they can play in these large plants and in the development of large use for coal, in coordinating some of the environmental matters better. We are in a stage in our history—there is no question this is important—none of us want to go backward in that direction.

We aren't even asking for all that much relief from the rules that we have, but we could certainly be helped if the time frame required to get environmental matters settled could be decreased, if the time required to get an environmental impact statement could be decreased.

Normally we aren't pounding on the table looking for relief of rules. We are looking for just getting decisions so we will know where we stand.

You know facetiously sometimes we say we can live with almost any rules if we just know what they are, and know that we are still going to have those same rules when we put a plant onstream 4 years later.

I think another way the Federal Government can certainly be helpful to the development of the coal industry is through certain incentives that can be given, tax credits, accelerated depreciation, and this sort of thing. In a very down year in industry, in our company, total corporate research is up 12 percent this year, but much of that as a result of some tax benefits that have been given to companies that increase their research programs this year. This is the kind of help that we feel is really important.

I would mention a little bit about what our company, what Conoco is doing in this area. What are the opportunities to improve the position of coal in the world?

Primarily we are continually assessing the realities of the marketplace. For example, in the synfuels program, there is no question that the price of crude oil has come down. A couple of years ago when it was $42 and higher prices being posted every month, we were all looking at going up toward $50 a barrel crude, and synfuels, the time for synfuels was here.

All of a sudden we are back down to $34 crude and many spot markets at $26. And the crude prices just eliminated the real economic incentive to go forward in the large plants.

I think all of us know that this is a temporary pause, and we ought to all be smart enough to use this pause to improve our position, rather than just quitting and coming back to another crisis with gaslines and get into crisis management all over again.

As far as our company is concerned, we have shelved projects that require expenditures of multibillions of dollars on the basis that they are not economically sound now. We are continuing considerable development of the technology. The biggest single thing that we are doing is trying to develop markets for methanol because we believe methanol derived from a coal-based gasification process is the first thing that will be truly economic on a massive scale that will allow large-scale use of coal in synthetic fuel plants. But it now looks like it will be in the nineties before this really takes place.

This is an economic matter. There is just no question the price of crude is going to move on back up, and is going to be in short supply. The people who are accurate in predicting when the synfuels industry is economically justified are the ones who will make money.

On the other hand, we believe that the 1980's offer great opportunities for the direct utilization of coal in both the electric utility market and especially in the industrial sector. You know as a backout for oil, or as a use of coal where oil is now used, there are some 3–4 million barrels of oil per day in this country today that could be replaced by coal. Obviously all of that is not going to happen.

If all of that replacement did take place though, it would be an instantaneous addition of about 700 million tons of coal in this country, which would about double the present coal. Obviously that is not going to happen, but it is almost an infinite opportunity for very clever people to increase the utilization of coal in the future.

You know coal was king a few years ago, back when $4-a-ton coal was cheaper than $1.50-a-barrel oil, and coal was actually a larger fuel in this country than oil and gas. For a long period oil and gas literally got cheaper than coal, and it was a cleaner burning thing.

We are now at the situation where oil at say $30 a barrel is the equivalent to $5 per million Btu's. Coal at $25 a ton is equivalent to $1.50 per million Btu's. The difference in those two numbers—$3.50 per million Btu's—is the money that we have to spend in developing technology to utilize coal in places where oil is presently being used. There are a number of technologies that are being developed today that will allow us to use coal as a replacement for oil, and in a way that they will be environmentally acceptable to this generation.

We have shifted our own research effort over the last 2 years to include about 75 percent of all our money being spent on the direct utilization of coal in utility and industrial markets, and we really believe that the need of the 1980's is to increase the amount of coal that is going into the electric utility and into the industrial market as a replacement for oil.

The oil back-out opportunities—and I did come thinking we might have 35 mm slides, and I had some slides to sort of give you some of these estimates, but I think the exact numbers are really not important. The important thing is there is an economic incentive today to use a great deal of coal as a replacement for oil in this country, if the technology improvements can be made to the extent that these replacements are environmentally acceptable.

That is the only holdup that we have right now. The economic incentive is there, and it is by far the greatest incentive, the greatest drive that you can have toward developing the utilization of coal, and most of the activity of our company, and we believe that an increasing amount of support from the Federal Government, should be in the direction of supporting direct utilization of coal as a way to increase coal use in the 1980's, and not completely forget about the synfuels program, because its time will come, but clearly it is not going to come in the 1980's.

Thank you.

[The prepared statement of Mr. Sudbury follows:]

Statement of John Sudbury

I. INTRODUCTION

Good morning, gentlemen. My name is John Sudbury, and I am speaking for the Coal Research Division of Conoco, at Library, Pa. I have been with Conoco since obtaining my doctor's degree in chemistry at the University of Texas in 1949, and I directed the coal conversion and utilization research effort of Conoco, formerly the Research Division of Consolidation Coal Company, for about eight years.

II. THE PAST ROLE OF THE FEDERAL GOVERNMENT IN COAL RESEARCH

As you know, the Federal government has played a significant role in coal R&D in recent years; i.e., for at least the past 15, through the mechanism of first the Office of Coal Research, Department of Interior, succeeded by the Energy Research and Development Administration, and currently by the Department of Energy. Most of the financial participation by the Federal Government has been by way of mechanisms which of necessity have been funded on a year-to-year basis, which is not fully conducive to a long-term research environment.

Consolidation Coal Company and its parent Conoco Inc. (now a part of the Du Pont Company) have been actively involved in coal R&D over the years with these Federal agencies to the extent of having spent as prime contractor more than 100 million Federal dollars in four major and numerous smaller programs. Briefly, the four major programs were the Consol Synthetic Fuel Pilot Plant at Cresap, West Virginia, which was the first Federal direct liquefaction effort, "Project Gasoline," the CO_2 Acceptor Process through the stage of highly successful pilot plant operation at Rapid City, South Dakota, the zinc chloride direct coal liquefaction Process Development Unit at Library, Pa., and the British Gas Corporation/Lurgi slagging gasifier demonstration project Phase I design to have been sited in Noble County, Ohio. We have contributed private corporate dollars as financial participants, in conjunction with Federal agencies, to the extent of over $4 million in the H-Coal pilot plant project at Catlettsburg, Kentucky, and, together with Shell Development, something over $1 million in the zinc chloride project.

In our own experience these joint projects with the Federal Government did advance the development of the technology and permit a better assessment of the commercial potential of the projects. There was not, however, in the DOE system a feasible way to plan, fund, and operate a commercial-scale demonstration project. The Federally-supported demo projects inevitably bogged down in trying to satisfy a multitude of constraints or, to use a cliche—to be all things to all people. How many and what kind of coals to test, what level of environmental controls to be implemented, and how many different types of processing equipment to be tested were typical of the almost unsolvable problems encountered.

Conversely, when commercial conditions are right, private industry can move expeditiously. Tennessee Eastman has elected to install a commercial demonstration of the Texaco gasifier at their Kingsport, Tennessee plant without any Federal support. They had only to consider the coal sources near their plant and the specific environmental regulations for that site. Obviously, they decided it was time for a demonstration of an advanced technology and moved to implement the project.

III. THE FUTURE ROLE OF THE FEDERAL GOVERNMENT IN COAL RESEARCH

We believe that there is a very important and necessary place for the Federal Government in future coal research and development. Perhaps the most important role is to supply some funding for continued research on truly new, innovative concepts of mining, beneficiation, transportation, utilization or conversion. Quite often our colleges and universities, and to some extent individuals and small businesses, are the source of some exciting ideas for novel processing, but they lack the financial resources to test the concept on even a rudimentary scale. While U.S. corporations do support academic research, some schools may not share proportionately in the funding and need assistance. Federal support of some academic research is desirable also to maintain a strong faculty in these schools. This assures a continued flow of technically-trained people for the future needs of the country.

A second important function of the Federal Government in future coal research should be to coordinate and expedite the environmental aspects of coal utilization and coal conversion. Interpretation of environmental data and enforcement of existing rules is now fragmented among many agencies—both Federal and State. We need to simplify and speed up the process of getting the necessary background data and the permits to operate.

In our opinion it is not feasible for the Federal Government to participate in the commerical demonstration of new coal processing technology. A Federally-controlled demonstration must satisfy too wide a spectrum of demands to be efficient or cost-effective. However, the Federal Government can and must play an important role in defining and implementing effective tax regulations and other fiscal incentives that will enable the private sector to go forward in commercializing new coal technology. Accelerated depreciation, and R&D tax credits are examples of incentives that must be in place.

IV. CONOCO'S COAL RESEARCH PROGRAM

At Conoco we have structured our present and future coal research program to conform to the realities of the market place. We perceive that the major markets for coal in the near term will be in direct utiliztion of coal-steam raising and electric power generation and production of coke for the steel industry.

Our 1982 coal research budget is over $10 MM. This expenditure is dedicated to direct coal utilization and coal conversion in projects as diverse as:

1. transportation of coal from the mining face to the prep plant,
2. degasification of the coal seam prior to mining,
3. beneficiation (or cleaning) of coals,
4. recovery of coal from waste ponds and "gob" piles,
5. combustion of coal, both conventional pulverized coal firing and fluidized bed combustion,
6. desulfurization of products of combustion commonly known as flue gas desulfurization,
7. production of metallurgical coke, and
8. conversion of coal to synfuels, both liquid and gas.

When the market for synfuels in the U.S. is viable and the appropriate fiscal incentives are in place, Conoco is prepared to move into the coal conversion arena without Federal support. In the interim, we plan to continue our own aggressive research program.

Mr. WALGREN. Thank you very much, Mr. Sudbury. We appreciate that testimony. Dr. Williams, welcome.

Dr. WILLIAMS. Thank you, Mr. Chairman. My name is Max Williams, and I am the dean and professor at the school of engineering, University of Pittsburgh, but specialize in aerospace primarily, and I find myself a little bit out of the ground, if you do not mind the slight pun.

From the point of view of my previous colleagues' remarks here today, I will not go into my written testimony, which I would like to have a matter of the record, but I would like to amplify some of the remarks following generally my testimony.

I find that I am not very much in disagreement at all with the remarks made by the previous speakers.

I would like to say, though, with respect to coal-related research and the characterization of coal, I think there are two major objectives that I would like to emphasize, with respect to needs. One is the increased productivity which must be consistent with safety.

Second, we must have efficient energy conversion. That must be environmentally acceptable.

As to both of these, they require what I feel is an extremely important aspect of strategic planning, not tactical. The strategic planning has been remarked upon by the previous speakers in terms of short range, long range, the inability to have time to carry things through to completion.

What I would like to suggest is that we do concentrate on better strategic planning. It is difficult, but I feel it is mandatory that it be accomplished.

There are a couple of comments that relate to strategic planning. One of these is one that we call in the engineering business the characteristic time. It takes longer these days to do things—5 to 10 years to open a coal mine, to build an airplane. This characteristic time is now even longer than the statutory elective time of the officers of the Government. As a matter of fact, even for certain deans and professors, so it is taking time to get the jobs done these days.

It is much longer than the time that the doers and the regulators and the administrators have to finish them, so it is imperative that we figure out in this country some way of accommodating sufficiently accurate and precise strategic and long-range planning.

This also relates very much in terms of strategic planning to which projects you choose, which you adopt, and which you carry through to completion. Mr. Sudbury has referred earlier to the inability to complete some of these projects that have been started. The massive demonstration plants completed by the Government. The projects themselves have not necessarily been completed.

I think what is faced therefore with the problem of when you choose a few projects, which you do carry through to completion, and replace these perhaps, not necessarily large ones, is whether you replace these instead of what seems to be the current attitude of many, that many projects are adopted and then dropped halfway through with what engineers would tend to view as no completion of the experiment on which we can then base later decisions.

There is an essential ingredient in what I have been saying as to how to conduct this strategic planning best, and that is the necessity to make, as many of you recognize, the cost-benefit analyses. We are living in that type of time, where cost-benefit analyses are important, tradeoffs are important.

I mention in this connection, particularly in the written version, the situation of the robots in Japan, how the Japanese are taking over our automotive industry. You know, robots by themselves are not new. With the Japanese, however, they were smart enough to choose the correct time at which the robots were accepted, put those into production in proper plants, and make money at it.

The second part of this relates to the subject of these hearings. Japan itself is not a coal producer. It is amazing, but when you think about it, they do not have coal mines of any substantial quantity, but they have been making a very great business of the product of technology, selling technology, selling plants, and making money at technology transfer, by buying and selling everybody else's technology that they can beg, borrow, buy, or steal, doing it at a profit, and I think it is particularly important that we learn how to cope with that problem.

I was very interested to read—as I have quoted in the paper here—a statement of Kurt Yeager, attributed to him in EPRI Journal: "Japan's success is based upon a willingness to objectively evaluate equipment options and design, operations, and maintenance practice on the basis of value, not past practices and tradition," tradition coming from a country like Japan.

What that translates into, with no reflection on the National Institutes of Health, is what we call the NIH syndrome. That, in our parlance, is "Not Invented Here," not National Institutes of Health. There seems to be in many parts of the country, and I do not exclude Government or industry from this particular difficulty, of tending to do things the way we always have done before, and that is one major thing that the Japanese have not done.

They have chosen to pick up their information wherever they need it, buy it wherever they need it, but make it sell at a profit. So this type of thing in terms of the cost-benefit analysis leading to our excitement with technology transfer abroad might suggest to us that a direct coping with the NIH syndrome of how can we effectively combat that in this country would contribute, in my opinion, to improved strategic planning and permit a long-range improvement.

Can we learn any lessons? There is just one that I would like to add in addition to, let's not have this NIH syndrome anymore, and that is carrying it through and, emphasizing one more time, carrying through our experiments to completion. In this tradeoff, I mentioned before, how you pick the experiments is not necessarily as important as getting the completion of the experiment to a decision point that can be a data base for further action.

I think in this connection, I would like to emphasize a descriptive footnote in my written presentation with respect to management practices. Mr. Carter, when President, went about, as some of us have facetiously said, redesigning the automobile. He did this with the proposition for $100 million per year for 10 years as a proposed program called CARP—cooperative automotive research program.

I am not going to address the pros and cons of that particular program, but rather as a management tool and as a device for trilateral collaboration between universities, industry, and the Government. This was a mechanism. It was a mechanism by which we could potentially compete on a cost-effective proper basis with Germany, with Russia, with Japan. What it did was permit and construct—by the way, I will refer you to the footnote—a mechanism and a coordinating council that would permit us in this country to let industry sit around a table and trade ideas without having Mr. Sherman and Mr. Antitrust outside ready to take them off to jail.

Some mechanism must be accommodated so that we can put the trilateral collaboration together.

In conjunction with that, my comment in the paper says that in short, there will be a long-time change in the relative proportion or a mixed distribution of our energy resources. This is page 5. Strategic planning is mandatory. Technological development will play a very important role and the United States has the present base and the interest to participate, as Dr. Sudbury, Dr. Ray, and Dr. Chun have already indicated.

With judicious Government assistance, not all necessarily in direct dollars, but possibly through the aforementioned tax incentives, and stability in its imposed Government environmental regulations in fiscal policies, note the word stability, essential to long-term strategic planning, we should collectively be smart enough to figure out a way to maintain our national pride, economic health, and international stature.

Now if I may, just a few words about the research in universities. That is really my primary business, Mr. Chairman. I want to emphasize just as strongly as I can that I do believe that R&D pays. It pays substantially. It is very hard to quantify it. I have indicated in the testimony the illustrations that have been made in previous times by previous organizations in studies, three or four that have attempted to make a direct coupling between the cost of research and its practical payoff in terms of return on investment.

These have not been unilaterally successful, but I believe there is a very strong subjective proof that it does pay.

Now we get into this standard argument of how much to put into research. I do not want to argue this particular point. I would much rather advocate a philosophy that I have espoused for quite some time. That I would prefer a fixed percentage put into research in this country, and then argue about the proper utilization of that fixed amount of money for maximum payoff, and let the people that do the research, generally speaking, conduct the apportionment of those funds among the research community.

There are going to be cat fights, but let's accept that.

I view this as literally insurance policies against technological surprise, so we pay a certain amount of money, as this insurance policy, set that aside for research, and say that is our premium that we must pay to avoid technological surprise, and in the international arena, that is what it is all about.

I have a somewhat apocryphal story perhaps. My wife has been a member of the GE executive family for many, many years, and this has been passed down and it may not be attributed to GE, but that is the way the story comes out in our family. I understand the way it went was at one time, the chairman of the board walked into a meeting of the board of directors and his principal executives at the General Electric Co. and said:

> I have been concerned about research. What I have decided we are going to do is put 5 percent of gross sales into the research fund at our R&D laboratories, and I am going to put them in Schenectady.
>
> Now all of those of you who do not agree with that will signify by handing me your resignation.

The matter was settled. Now that the percentage has been settled, you all figure out how to get the most out of it.

I would like to deal just one moment with this important trilateral collaboration. I am from the universities. I think universities do have something to offer the country in coal-related research, in research in general. First of all, the universities and particularly the engineering schools need you. We particularly appreciate the kind of effort that this committee has done in making our cause known to a wider branch of the Government, and indeed to a wider branch of the American public.

We have the well-known problems, faculty shortages, shortages of graduate students, native born, who are American citizens. We have the shortages of equipment, and parenthetically I would like to remark going along with this is the importance of the subject of instrumentation technology, because in this particularly important area, it is important to have equipment which can measure the quantities of emissions in the air. That is one illustration of the importance of instrumentation technology.

It also affects CAT scanners, if you have heart trouble.

Another thing that has bothered me particularly, being an aerospace type, is that in Seattle they many times have been writing up how taxicab drivers used to be engineers in aerospace at Boeing. That is the best job they can get. That is not that they really were out of a job. They did not want to leave Seattle, my friends in Seattle tell me. Employment in engineering has always been substantially less than the national average, but we are subject to some bad PR, and it gets blown up out of proportion in the press.

Too frequently high school counselors pass that type of information on to the high school students. The high school students hear it, and we have the boom-and-bust cycle. This boom-and-bust cycle is the same type of thing that happens like in mining engineering, where we have many engineers and no jobs, and then we have many jobs and no engineers.

Parenthetically, I might say in trying to make my own survey and assessments of where the University of Pittsburgh should stand in mining, I took a poll of five chief executive officers here in the city, just 2 or 3 years ago now, and said, I am faced with that standard problem where it looks like in the future we are going to be out of mining support very shortly. What do you suggest I should do about that?

Should I shut down the mining department for the second time? We started it again in 1974.

The unanimous advice came back, hang in there, Max, by all means keep the schools open. We are going to need them in a period of 5 to 10 years, so we can smooth off that boom or bust cycle.

Now the universities not only need your help, but I think we can help you. We can do the best in a trilateral arrangement, where we cooperate among the universities, the industry, and the Government. My personal opinion is that we have a very natural vertical integration that I comment upon in the paper, and you can almost view the university, and particularly the engineering schools, as a tree, and you can hang almost all parts of the development of energy conversion, mining, excavation, exploration, geophysics, all as parts of these trees in various of the normal departments of a normal engineering school, a normal university.

It includes environmental health in our own Pitt Graduate School of Public Health, biostatistics, biology. All of these things can be fed into a common contribution that the universities can make if they stay healthy in the research areas.

One final comment on technology transfer that two other speakers have previously referred to. It seems to me that most of the comments in this country have related to how fast people are stealing technology transfer from us, all the way from the first time Dr.

Kissinger made the first arrangement to give it away until very, very recently. Sometimes it may escape your attention that there is another thing that has not been done properly, and that is reverse technology transfer.

I admit to somewhat of a personal hangup in that matter. I think we can get technology from abroad. These are the days when we are unable in this country to be expert in everything as we were during World War II, for example. We can no longer be all things to all people, or else we will end up being jack-of-all-trades and expert at none. We must choose our priorities by strategic planning. I say, select those areas in which we are to be expert, and I would propose we try to get the rest of those omissions the best way we can, and one is by reverse technology transfer.

Why do we not do it? The common answer is lack of language. We have a language barrier, lack of familiarity with foreign languages and the translation of foreign papers.

I would like to give you just one personal illustration if I may. I recall it was in May of 1966 I gave a paper in one of the hotels in Los Angeles on a very up-to-date summary of the solid propellant rocket motor situation in the United States. That paper was given in May 1966 and 6 weeks later the Central Intelligence Agency delivered to me a copy of my paper in Russian on my desk, 6 weeks later, asking me to have it translated and check the accuracy of the translation. That is how fast their technology transfer works.

I think in times when we are trying to fill out the omissions in those areas that we are not qualified, by choice, but we wish to maintain and follow along by some reverse technology transfer, it might be high time to review how much effort we are putting into the area of our own language capability and our own center for absorbing, accumulating, and disseminating foreign technology information, whether it be to government, to industry, or to the universities.

I would just like to conclude by thanking you, Mr. Chairman, and the committee for the opportunity to appear in front of you, but I feel we must see that the economic exigencies and short-range planning do not destroy or mitigate the use of universities. Rather, methods for making more effective use of them in an increasingly effective trilateral collaboration with the Government and industry must be collectively and constructively exploited.

Thank you, sir.

[The prepared statement of Dr. Williams follows:]

MAX L. WILLIAMS, JR.

Professor Williams, a native of Pittsburgh, is Dean of the School of Engineering at the University of Pittsburgh, having come there in 1973 from a similar position at the University of Utah in Salt Lake City. After graduating with a bachelor's degree in mechanical engineering at the Carnegie Institute of Technology, Pittsburgh, Pa., in 1942, he spent four years in the Air Force before entering the California Institute of Technology, Pasadena, California, for graduate work and his master's, professional, and doctorate degrees in aeronautics. He remained on the faculty there as Professor of Aeronautics until leaving in 1965 to accept the deanship in Utah.

Aerospace engineering is Professor Williams' primary field, with a specialty in structural mechanics and materials of construction, more specifically in the mechanics of fracture. He founded the International Journal of Fracture in 1965 and remains the Editor-in-Chief. He has published over 150 research papers, is a registered professional engineer in California, Louisiana, Pennsylvania, and Utah, and has consulted extensively with industry and various agencies of the government, mainly the Department of Defense and the Department of State.

Professor Williams has served in Pennsylvania as chairman of the Governor's Oversight Committee on the I-79 Bridge Failure in Pittsburgh. In Washington, he has held memberships on the National Science Foundation Advisory Committee for Engineering, the National Institute of Dental Research Committee on Biomaterials, the NASA Advisory Committee on Rocket Propulsion, and the National Materials Advisory Board. His most recent service was as chairman of the Structural Mechanics Subcommittee of the OSTP Committee on the Automotive Research Program (Project CARP) in 1979-80.

COAL-RELATED RESEARCH AND CHARACTERIZATION

It is tempting to become involved in further discussion of energy supply and demand, and particularly the potential oil shortage and the background for it. Fortunately a substantial need for coal as the mainstay for our longer-term energy supply is not disputed. Indeed by the year 2000, the 1981 Energy Information Administration Report to the Congress[1] projects that, domestically, coal will not only supply more of our internal supply than oil and natural gas combined, but that it will become a substantial export product. (See Table 1, attached.) With this type of confidence in the future of coal in this country, it is indeed proper for the committee to review our national position with respect to it in research, production, and use as a basis for future planning. The "knee jerk" reactions of the early seventies, the crash programs we embarked upon, and the societal and manpower concerns we continue to hold should be critiqued in the present political and economic climate.

I note first that strategic planning in this country at times seems inordinately difficult. Barring of course a national calamity or a national popular objective like landing on the moon, we too often seem unable to "follow the blueprint" long enough to obtain reliable operational experience. I would like to hope that the basic elements of an efficient, long-range strategic investment plan could be put in place, with digressions the exception rather than the rule. Unfortunately, tactical planning seems to be much more compatible with our present way of life and the normal lengths of service in the legislative and executive branches! On the other hand, if the long-range strategy is clear, short-range deviation and change along the way for cause can be cost-effective and helpful.

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[1] C. Lawrence and E. Hollander, "Energy Forecasts by EIA," EPRI Journal, May 1982, p. 24.

Objectives

Granted that coal will be a major component in our future, it seems to me that we need (1) increased productivity consistent with safety, and (2) efficient conversion that is environmentally acceptable. The former assumes the existence of a strong technological base in exploration, extraction, and delivery systems, while the latter requires an exploitation of standard and possibly high-risk methodologies of energy conversion in conjunction with environmental control technology responsive to reasonable environmental restrictions and, possibly, the current public perception. Both are subject to cost-benefit analyses, with due weight being given to the particular contribution's place in the research and development cycle, and the nature of the risk being taken and by whom. This observation is based upon industry's usual willingness to invest when it becomes convinced of a pay-off, although frequently the federal government must stimulate particular research or a special development because of the inordinate expense incurred in demonstrating feasibility. The main challenge for government is to pick that transfer point which guarantees a return on its investment without blind persistence based upon potential embarrassment. On the other hand, industry must resist the "NIH-Syndrome*", i.e., doing things the same way we always have, usually with an eye on the short-term pay-off.

The Japanese adoption of robotics is a case in point. This technology is by no means new. By a shrewd observation that the time was ripe for production innovation in conjunction with some modifications to the workers' sociological contributions ("quality circles"), plus the cooperative and non-adversarial roles of industrial, banking and government officials, a deliberate invasion of the automotive market was successfully undertaken. The basic ingredient was exploitation and expansion of an existing technology, not the invention of a new one.

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*NIH = Not Invented Here

More to the present point, Kurt Yeager, director of EPRI's coal combustion system division has reported[2] on the new Japanese 100 megawatt conventional pulverized coal-fired plant at Matsushima near Nagasaki. Ten years ago, the Japanese utility industry used no coal; and negligible coal production. Now Japan is rapidly becoming a world leader in applying this state-of the art--as a matter of good business by buying technology when needed, or obtaining it free from the literature for exploitation by its engineers--at a profit from whoever is prepared to buy. Yeager points out Japan seems satisfied for the present to leave revolutionary technology to others, but make substantial money and reputation on the research and development of others. From the "NIH" point of view, Japan's success is based upon a willingness to objectively evaluate equipment options and design, operations, and maintenance practice on the basis of value, not past practices and tradition.

Exploitation of our technology and markets is not confined solely to the Japanese. West Germany and Great Britain as well see an energy vacuum created by the withdrawal of U. S. federal funding from coal research and development and are rushing to fill it with their own brands of innovation, engineering, and technology

The lessons we might learn are therefore (1) better integration of the federal, economic, and industrial objectives in strategic planning with reduction of legal hindrances, even between companies, to an absolute minimum,* (2) permit well designed experimental development to be carried through to completion, recognizing that frequently apparently probable negative overall project results may provide a substantial positive contribution to our technological data base, and finally (3) maintain a broad level of research competence and an open-mindedness so that we do not become the victim of an "NIH-Syndrome."

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[2] W. Nesbit, "Japanese Challenge in Coal Combustion Technology," EPRI Journal, May 1982, p. 20.

While the foregoing comments are somewhat critical, nevertheless the fact that we in the United States have had technology "stolen" certainly means we have not been idle in coal research and development and matters related thereto. For balance therefore, if nothing else, let me observe that our country has made major technological contributions to energy conversion technology, automated data acquisition and processing for mineral location and recovery, mine safety, environmental control, mechanical equipment for improved productivity, and has collaborated in worldwide studies in coal transportation by various means including planning for deep-water ports.

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*An interesting joint government-industry-university organizational experiment was tried in 1978-79 in the automotive field. Project CARP (Cooperative Automotive Research Project), coordinated from the Office of the Science Advisor to the President, was to be funded at $50M per year by the automotive industry (contributions proportional to sales) and $50M per year by the government both for a period of 10 years. The major performers of the research were to be university faculty members working under a joint independent technical steering committee which approved expenditures in ten relevant technical areas. Aside from some important benefits to the nation's engineering schools in terms of the emerging equipment and faculty shortages, which were never implemented because the project was not funded, the merit of what I thought was a splendid organizational idea was never evaluated. It represented a unique approach to involve the three communities--government, industry, and universities--in a legal, free-exchange arena where this triumvirate might attempt to compete with the well established, close operating arrangement common in many foreign countries, e.g., Japan, USSR, West Germany.

Despite the ups and downs of the synfuels development,* some projects are going ahead as described recently by J. W. Mares, Assistant Secretary for Fossil Energy, Department of Energy, in a speech to the Commercial Development Association in Washington, D. C., last month. The Tennessee subsidiary of Eastman Kodak is continuing work on a coal gasification plant in Tennessee with no government involvement at all; Dow Chemical is financing a coal gasification pilot project in Louisiana, and Exxon is moving ahead with a $500 million program in Holland to scale-up a large pilot plant. Simultaneously, American Electric Power (AEP), whose electric power distribution system is nearly wholly dependent upon coal, has been considering a $250M pilot project at its Tidd Plant which will incorporate pressurized fluid bed combustion, which is a conversion technique to remove sulfur from coal without the need for scrubbers. Interestingly enough these development costs are being shared with Germany and Switzerland. On the applied research side AEP has continued its former interest in magnetohydrodynamic (MHD) generation of electricity by cooperating with the federal government in developing an expensive new research facility in Butte, Montana, to be employed for testing components and power trains for new MHD systems.

In short, there will be a long-term change in the relative proportion, or mix distribution, of our energy sources. Strategic planning is mandatory. Technological development will play a very important role and the United States has the present base and interest to participate. With judicious government assistance--not all necessarily in direct dollars, but possibly through tax incentives and stability in its imposed environmental regulations and fiscal policies--we should collectively be smart enough to figure out a way to maintain our national pride, economic health, and international stature.

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*The most successful synfuel company is operated by SASOL in South Africa, although it benefits from a substantial government subsidy because of national security reasons.

Research and the Universities

Let me say a word about research and development (R&D) on a philosophical basis, particularly from the viewpoint of the universities. First of all, I am personally very strongly convinced that R&D pays--and pays and pays. From 35 years' experience in university research, coupled with frequent consulting experiences in the technical industries, with the financial community, and with various agencies of the government, I believe there is absolutely no question as to the importance of R&D. The key however is to place your bets accurately on the right subject, in the right amount, and at the right time. Sometimes the popular R&D expenditure comparisons are inadequate, as for example when an industry or country neglects R&D for some time and then must play catch-up, thereby distorting the percentages among the absolutes.

Confining myself now to the basic research arena, it is frequently hard to justify some investigations--mainly because if one knew what he were looking for it would not be basic research. Many attempts have been made to quantify its importance. Such efforts as "Project Hindsight"[3] by the Department of Defense in 1969, "TRACES" by the National Science Foundation[4] in 1968-69, and "Biomedical Discoveries Adopted by Industry . . . " by the National Institutes of Health[5] in 1981 come to mind. Generally the attempt is made to show the orderly progression of technical development from idea to basic science, to applied science, to exploratory and to then prototype development. It doesn't always work that way, but nevertheless there is, at worst, sufficient subjective evidence of basic research pay-off to prevent denial of its contribution.

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[3] Anon., Project HINDSIGHT, Final Report, Off. Sec. Def. (R&E), October 1969.

[4] P. Thompson, "TRACES: Basic Research Links to Technology Appraised," Science, 163, 1979, p. 374

[5] Anon., Biomedical Discoveries Adopted by Industry for Purposes Other Than Health Services, Off. of Director (Medical Applications of Res.), National Institutes of Health, March 1981.

Rather than present such a negative defense of research, I personally prefer that a fixed percentage of an appropriate unit budget, or for that matter of the gross national product (GNP), be defined as the research budget. With that amount settled, preferably for a long term as part of the strategic plan, thus implying affordability and competitiveness with foreign countries, the planners should rely upon the members of the research community to maximize the return on this investment amount. Adherence to such a policy would reducc criticisms of invididual projects or tasks, and being long term could be corrected if necessary on a strategic basis. In a sense, such an investment would be similar to an insurance policy to forestall technological surprise. The approach would be sold solely on that basis, and perhaps negate the frustration in the Senate that, in the Department of Defense case, led to the Mansfield Amendment which required a proven relevance between the proposed research and the defense mission.

Such a philosophy depends for its success upon the distribution of the available funds among the doers and their respective constituencies. Here I would urge reinstatement of a strong tri-lateral collaboration among government, industry and the universities. Recent economic events have had one strong positive effect. There has been an increasingly bi-lateral awareness of the interdependence between industry and the universities as to manpower and research. The highly visible action of Exxon in celebrating its 100th birthday by distributing $15 million to university engineering schools for alleviating the faculty shortage and technical equipment deterioration is now well known. A continuation of this bilateral collaboration, along with the other two interactions of university-government and industry-government, would in turn strengthen the trilateral collaboration and, ultimately, the R&D support and the cost-effective distribution of available funds.

Finally I might say the current general problems in engineering schools today are well known, certainly to your committee but increasingly to the man-in-the-street.[6] Briefly they are: Engineering faculty shortages, industrial attraction of B. S. graduates at high salaries thus reducing the graduate student "pool," disproportionately high numbers of foreign graduate students, and low budgets for laboratory equipment maintenance, repair, and replacement.

Coal Mining

The energy shortage has exacerbated the situation, especially in chemical, petroleum, and mining engineering; indeed, for all the energy-related technologies. As an illustration, consider the situation in mining engineering, specifically in underground excavation of coal. (As far as the government's present organization is concerned, mining engineering research is the responsibility of the Department of Interior through its Bureau of Mines. *) Anticipation of the Department of Energy's reduced activities in coal has probably contributed to, but not been primarily responsible for, the decline in undergraduate mining engineering enrollment in coal-related schools--the first pool from which graduate students for research and subsequent faculty are drawn. Table 2 below depicts this decline in enrollment for six of the schools most closely associated with the coal industry, as compiled by Consolidation Coal Company. (Data for Ohio State and Southern Illinois University were not available.)

Table 2 - Undergraduate Enrollment in Mining Engineering

	79-80	80-81	81-82
Alabama	150	138	93
Kentucky	142	203	127
Penn State	912	316	256
Pittsburgh	150	135	103
Va. Polytech. Inst.	227	231	184
West Virginia	430	345	253
Totals	1511	1368	1016

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[6] S. Barlas, "Cuts at Colleges Wrecking Supply of Engineering Grads," The Pittsburgh Press, April 26, 1981, p. B-17.

*For the four years, FY 78-FY 81, DOE placed only $2.6M of its total $50M university contracts into mining engineering research, as distinct from research in coal preparation and cleaning.

It is interesting to note that until this spring, nearly all of our University of Pittsburgh B.S. graduates were quickly employed by industry. Our largest class of mining engineers, 75 in number, departed last year, as compared with 30 the previous year and 34 this year. Even in the face of uncertain business conditions there was sufficient growth in the industry to accommodate that bumper crop. In 1972 there were 15 schools offering degrees in mining engineering and related areas. Shortly thereafter we were the first to reactivate a mining program. Now there are 25. The demand for faculty however has increased far beyond the supply. In 1980 the MITRE Corporation reported:[7]

> "A major near-term problem affecting the supply of mining engineering graduates is the difficulty of mining schools in attracting sufficient faculty. The level of full time equivalent faculty engaged in research has declined dramatically since the 1973-74 academic year. The remaining faculty resources available for teaching has resulted in effective student/faculty ratios of between 30 and 40 to one in most schools. The Engineers Council for Professional Development (ECPD) has defined 20 to one as a desirable maximum ratio of teaching faculty to undergraduate students. Thus, a need exists for attracting more faculty to reduce undesirable teaching loads, as well as to perform more research related to the improvement of mining technologies and labor productivity."

While the current declining job opportunities and enrollments would seem to relieve an unsatisfactory student-faculty ratio and might even make it possible to increase faculty ranks by increasing the number of students going on for advanced degrees, the loss of federal research funding from DOE, BOM and MSHA undercuts the base of support for many faculty and makes an academic career even less attractive that it was.

While engineers, particularly in the aerospace technologies, are accustomed to the boom-to-bust cyclic nature of their employment, such instability is probably not conducive to an orderly progression of high school students into engineering careers. Unfortunately the media tends to seize upon "ex-engineers driving taxi-cabs," which frequently translates more directly than we would like into impacts upon engineering enrollments via high school counselors. Actually, unemployment in the engineering field is substantially below the national average, at all times! As Abelson has recently pointed out,[8] the future in engineering and science is continually before us. It is becoming more complex and technocratic. It behooves us to do our level best to minimize the amplitude of the booms and busts, and thus maintain a reasonably stable technical constituency over the long haul. Again, there is an appeal for effective strategic technological planning.

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[7] "Manpower for the Coal Mining Industry: An Assessment of Adequacy through the Year 2000," Report to DOE by the MITRE Corporation, March 1980.

Environmental Technologies

Technologies for handling toxic and hazardous wastes from coal utilization are not being adequately developed by the private sector. The private sector tends to develop "tack-on" devices for generic application; the coal utilization developer then depends upon the Environmental Protection Agency (EPA) for regulatory guidance in using such "tack-on" devices to make the new facilities legally acceptable. As exemplified by the 1982 regulations issued for the iron and steel industry, the EPA looks towards existing "model plants" in developing its regulatory guidance. But model plants for synfuels and advanced coal utilization systems, for example, do not exist in the U.S. Thus bankers shy away from investing until they can be assured that environmental permits issued at the local level will be granted, sites can be developed, and public intervention in the permit-granting process can be minimized. Concurrently, insurance underwriters will require high premiums, if insurance is even available, to cover risks associated with chemical and biological interactions of wastewaters and solid/hazardous wastes associated with coal utilization technologies.

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[8] P.H. Abelson, "Employment of Engineers and Scientists," Science, 16, 11 June 1982.

The public has already been sensitized to the existence of potentially toxic organics and heavy metals that can contaminate surface and ground waters. Long-term process research in the area of coal extraction and utilization must accompany environmental characterization and environmental process development research to assure the public that ultimate adverse health effects have been accounted for and minimized either by process changes or by advanced linkages among the environmental control technology operations. Environmental research that can not be linked to coal utilization is often not relevant to the question at hand. The Fossil Energy Division of DOE, in conjunction with the Energy Technology Centers, is the only group in the U.S. I know of with the capability of supervising coal utilization research coupled with the generation of realistic quantities of liquid and solid waste residuals to produce meaningful results in environmental health research. Continuing long-term research, funded by coal science and technology groups with the span of activities and visual horizon of the Fossil Energy Division, is necessary to assure the cleaner and more efficient use of coal in our environmentally conscious society.

All in all, a strong technical underpinning, embracing engineering, public health, and instrumentation technology must accompany the decisions on restrictive environmental regulations in order to complete the cost-benefit assessments between the economic impact and the legitimate social concerns.

Health Considerations

In today's environment one can hardly escape the questions of interaction between increased utilization of coal and the concomitant impact upon public health such as already implied in the previous section. This concern is reflected, for example, in restrictions placed upon sulfur dioxide (SO_2) emission and the recent publicity over acid rain. While there seems to be some compelling evidence that SO_2 may not be as harmful to human beings as originally anticipated--thus suggesting a possible relaxation of the early stringent emission limitations with an accompanying cost reduction--my immediate purpose here is not to discuss the SO_2 problem, per se, but to suggest yet another area in which a combination of instrumentation technology, epidemiology, and adequate biostatistics might together yield a better socio-technical evaluation than hereto enjoyed.

The question of acid rain is another illustration of the need for adequate quantitative information, to be gathered in the public interest and analyzed within the context of what an informed public wishes to pay. Unfortunately this particular subject, which has been studied by several prestigious groups[9, 10, 11], appears so far to have withstood resolution. The Jason Group[11] makes a very persuasive case for establishing a lead agency to prepare a substantive research plan with contributions from all interested parties and agencies, but arranged to be administratively and perceptually unbiased. In the meantime, caution would be advised while the debate and the studies continue. To reiterate, however, my special point at this time is not to draw conclusions, particularly premature ones, but rather to highlight yet another coal-related area which requires elucidation in order that an informed electorate may make its choice using technology as an aid.

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[9] Anon., "Atmosphere-Biosphere Interactions: Toward a Better Understanding of the Ecological Consequences of Fossil Fuel Combustion," Comm. on Atmos. and Biosphere, National Research Council, 1981.

[10] R. Friedman et al, "Long-Range Transport Air Pollutants," Draft Staff Paper, Office of Technology Assessment, September 1981.

[11] J. Chamberlain et al, "The Physics and Chemistry of Acid Precipitation," Jason Tech. Report 81-25, SRI Int'l., November 1981.

Concluding Remarks

My concluding remarks are directed again primarily to the place of research in an engineering school--and in a university--with respect to the massive responsibility anyone bears who has an important hand in directing national policy toward the cost-effective, competitive, and socially responsible utilization of coal as our major energy source over the intermediate term.

To me there are no obvious "quick-fixes," although there are some simple direct steps that seem to me as yet untried. As a simple example, let me reiterate an earlier comment about the "theft" of our research and technology, bought and paid for by Americans. While such transfer of technology abroad is commonplace and accepted in international business affairs, we seem too often to be on the "giving" end. Why is it that we have not established, except perhaps in limited areas related to national security, a reverse reciprocal capability to "borrow" from our competition abroad? A simple answer is of course the language barrier and a basic foreign language incompetence which is prevalent in the United States. But one questions nevertheless whether a massive foreign technical translation and subsequent information dissemination capability to our engineering and scientific communities--as our competition has used for years--might not be one very cost-effective, direct step toward parity in these expensive times when we can not afford to do everything well, providing we can also learn collectively to side-step our own "NIH-Syndrome"!

Returning to the engineering school and its research, I can easily associate its infrastructure with a vertically integrated approach to (coal) energy-related research. First there is the prospecting, followed by extraction, transportation, energy conversion and distribution, and then efficient utilization--all within appropriate environmental and health restrictions. Not only are all engineering departments potential contributors--but there are other important natural university collaborators, as in the health professions. Various other components involve geophysics for location, mining for efficient extraction, followed by optimum distribution strategies, railroad, slurry, boat, or other transport systems which utilize operations research techniques and economic analyses. Efficient conversion processes require sophisticated knowledge of chemical processes, combustion kinetics, unsteady thermodynamics, fluid mechanics, materials behavior of retention vehicles, control theory and instrumentation. Also, systems analysis and power distribution electrical networking would be included. During all these steps environmental engineering and environmental health impacts must be considered, particularly from the engineer's point of view with respect to the fluid, gas or mixed media dynamics of the products, its residues, and disposition.

Such a vertical integration analogy emphasizes that in addition to its primary function of providing technically educated personnel, practically all the research disciplines within an engineering school could participate in supporting an extended energy-producing industry. Even more generally, the universities as a whole have a broad array of talent--both technical and non-technical--which can be readily drawn upon for cooperative research, and indeed later stages of the R&D cycle.

We must see that economic exigencies and short-range planning do not destroy or mitigate this national asset; rather, methods for making more effective use of it in an increasingly effective tri-lateral collaboration with the government and industry must be constructively exploited.

EIA ENERGY SUPPLY AND DEMAND PROJECTIONS, MIDPRICE CASE

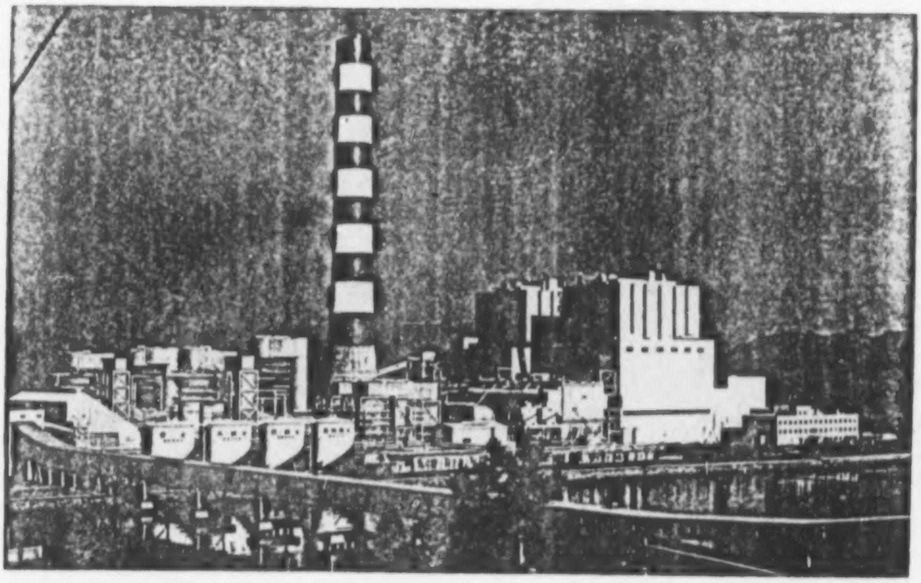
(quadrillion Btu per year)

	History	Projections		
	1980	1990	2000	2020
Domestic energy supply				
Oil	21	20	21	17
Natural gas	20	18	18	15
Coal	19	27	41	77
Nuclear	3	8	11	18
Other (hydropower, solar, geothermal, and biomass)	5	7	11	19
Subtotal	68	80	102	146
Net imports				
Oil	13	12	8	3
Natural gas	1	1	1	0
Coal	−3	−4	−6	−6
Subtotal	11	9	3	−3
Total energy supply	79	89	105	143
Domestic energy demand				
Residential	9	10	11	12
Commercial	7	7	9	10
Industrial	23	31	36	47
Transportation	19	18	19	19
Total end-use demand	58	66	75	88
Stock changes, accounting errors, and transmission losses*	21	23	30	55
Total energy demand	79	89	105	143

Source Energy Information Administration, *Monthly Energy Review*, November 1981, and *Natural and Synthetic Gas, 1980* (an Energy Data Report). Estimates of energy end-use consumption were based on data from the State Energy Data System. Projections were derived by using the LEAP model.

*Transmission losses are about 9% for natural gas and electricity

Table 1 (Reproduced from EPRI Journal, May 1982.)



Japan's current target for developing conventional pulverized-coal-fired technology is a 5000-psi (34.5-MPa) supercritical plant operating at 1200°F (649°C) with two reheats to 1100°F (593°C). The plant would also incorporate reduced power consumption by the auxiliary equipment and a higher performance by the air preheater. This is projected to provide a 7% improvement in efficiency at the busbar (from 36.7% to 39.3%) and to result in a coal combustion reduction of 160,000 tons a year for a 1000-MW (e) plant.

The capital cost increase over a 1000-MW (e), 3500-psi (24-MPa), 1000°F (538°C) single-reheat plant is estimated at $45 million ($45/kW), with annual fuel savings of about $12 million a year ($3/MBtu). For lower-risk steam conditions of 4500 psi (31 MPa), 1050°F (560°C), the additional capital cost is $27 million.

Technical issues identified for emphasis by the Japanese include verification of the reliability and long-term behavior of various alloys at high temperatures. Because variations in temperature and pressure, kind and quality of fuel, and flue gas composition may affect reliability, they feel this must be verified on an actual plant. Development requirements include high-temperature boiler tube alloys; two-stage superheat steam temperature control methods; design of turbine main steam valve, rotor, and blade material; and safety, shutoff, and drain valves.

These improvements would be developed in a step-wise manner to ensure reliability. Initial efforts begun in 1981 focus on qualifying materials at 1100°F (593°C) and then advancing to 1150°F (627°C).

Construction of a commercial plant incorporating 4500 psi (31 MPa) and 1050–1100°F (560–593°C) steam conditions is planned to begin by mid-1986 and to be completed in 1990. Beyond this, construction is to begin in 1990 and be completed in 1995 on a plant representing first commercial application of the full 5000 psi (34.5 MPa), 1150–1200°F (627–649°C) steam conditions. Estimated development costs over the period 1981 to 1987 are about $20 million. □

Mr. WALGREN. Thank you very much, Dr. Williams.

That is very interesting testimony from all of you. I cannot help but think you all put your fingers on a lot of truths, some in conflict with others, but nonetheless truths. If the numbers of bells that you ring that I have seen represented before, or made points that have been brought up for public discussion is any indication, it would seem to me that many in our society are starting to think along the lines of strategic planning and appreciating the balance that we must have, and hopefully that will lead our country in the right direction.

I would like to recognize Mr. Ertel for discussion and questions.

Mr. ERTEL. Thank you, Mr. Chairman.

I would like to reiterate what Congressman Walgren said. I have listened to your presentations. I find some interesting conflicts, but interesting policies decisions. For instance, I heard Dr. Sudbury say that I think if we took his analysis it all comes down to an economic judgment, and I compare that to Dr. Williams' judgment that we ought to make some strategic judgments.

I think they are in conflict. I think a strategic judgment can in fact include an economic analysis, but it takes in a much broader spectrum, a much broader range of considerations than just commissions, and I wonder how you compare those if we took Dr. Sudbury's analysis that we just let it come down to an economic judgment, when in fact it is opportune, from an economic point of view, to develop an energy source or to move into it as he suggested in the 1990's, but on the other hand we also know that we have policy considerations in this country concerning foreign affairs, national defense, the possibility of blackmail by the OPEC nations, which is getting less as time goes along as we get more energy independence.

How do we throw those into your economic analysis, and how do we have a strategic judgment that Dr. Williams suggests, if we only rely on the economic analysis?

Mr. SUDBURY. I will make one defensive comment.

Mr. ERTEL. I am not trying to put you on the defensive.

Mr. SUDBURY. When we reconcile our annual budget in our company, we absolutely do not choose only the projects that make the most money. We do choose direction. For example, we are committed to be a major party to an oil shale development jointly with Chevron and this is a project that will lose money for many years.

We do not always pick the project that has the greatest short-term economics. In fact, we have major exceptions to this every year, so I think strategic planning is absolutely a part of our own internal planning and I think absolutely should be even more so a part of the U.S. Government planning.

I am not disagreeing with that point at all, but I am saying do not ignore the economic situation.

Mr. ERTEL. I do not think anyone is suggesting that. I would just ask who makes these strategic judgments that you are referring to, Dr. Williams? Who makes those judgments as to what we utilize and how we make these long-range judgments?

We have also suggested that we set aside a certain amount of our budget, say 2 percent, 3 percent, whatever it might be, for research and development. Then you say once we have made that judgment, we let those people make their judgments as to the mix of the R&D.

Who makes those judgments for the mix of those R&D projects under your analysis?

Dr. WILLIAMS. Let me first of all say that I do not think that Dr. Sudbury and I are in any basic disagreement. I suggested the need for cost-benefit analyses. He happened to stress the cost in his presentation. The benefit is what he was referring to that would take place over quite a few years, so I do not think we have any basic disagreement on that matter.

As far as putting the money aside and letting the people that have the money, now that it is fixed, decide how it will be spent is clearly a major problem, but I think it is an acceptable problem, if one were to accept the fact that you are going to pay an insurance premium. There are a lot of people arguing about whether the premium is high or low in the automobile business these days, how it is distributed, who makes money out of it, whether parts of this should be devoted to certain social advantages or not, and that is a major area.

I do not deny it one bit, but I think it would be helpful if that area were decoupled from some of the other problems that in this case the Congress has to worry about. There are enough problems in Washington in setting the overall tone, in agreeing upon the overall strategic objectives, long term in the country, and I would personally think that the more subsets of problems, major subsets of problems that you could decouple, meaning that the interactions are reduced as far as possible—they will never be completely eliminated, but hopefully you could separate the kinds of problems that had minimal amounts of interaction from those that were hopelessly coupled, then spend your time with them.

That is a short answer.

Mr. ERTEL. I am not sure that I got my question across very well. Someone is going to have to make those decisions. Someone is going to have to make the decisions beyond the set-aside if that is what we can call it for R&D. Then we have to make the judgment, when you are talking about R&D how much we put into high energy physics, how much we put into coal research, how much we put into petroleum research, how much into nuclear research, or into health research.

Who should make those decisions, because once we have set that aside, we still have a series of decisions to be made in the allocation of funds within that set-aside. I noticed you talked about that, but I guess there has got to be a decisionmaking apparatus, and that decision must be made by somebody.

Who do you suggest makes that decision?

Dr. WILLIAMS. Mr. Ertel, I think we are part of that decisionmaking body right now.

Mr. ERTEL. You think the Congress?

Mr. WILLIAMS. The present system, emphasizing the trilateral as you are at this hearing. We have Government people, not only on your side of the table, but we have members of the executive branch here. We have industry, nonprofits, universities.

This is a trilateral discussion that I think is very important, that evolved from the kind of discussion, but just the fact that you have a House Committee on Science and Technology has separated off under the committee structure of the Congress an area in which hopefully you gentlemen will take the lead in setting the policy, with the input as you are getting now from the citizens and the industry.

Mr. **Ertel**. Then we come back to the next judgment. The administration has set criteria for acceptable research. That would be long range, high risk, high payoff, particularly long range and high risk depends on the state of the economy, because when you talk about payoff and risk and so on, determination is based a lot on what is happening in our economy today.

Now it seems to me that we have high interest rates in this country. Oil prices are soft, and therefore you can anticipate that many of the investments we would make today, based upon today's economy, are going to be very, very long range, if those are continuing conditions, so what effect does this have on the energy industry's willingness to invest in any kind of research, as compared to us?

If we go out on those very long-term payoff propositions, then there is a hiatus. There is some area in the middle, and what will industry do? Will they pick up that hiatus, so that if there is a bump or a blurp in the economy, will we be prepared? I suspect all of you ought to answer that question, because that is really what concerns me, if we are just going to be looking at that very long-range research, because we cannot just say that industry will always pick it up, because industry has different criteria, in evaluating projects, just as Dr. Sudbury has, and I am sure everybody else has a different criteria within their corporation, so are we really prepared for that intermediate to short range?

Mr. **Sudbury**. My argument is if you stay with science and technology, and leave the project development part off, you stay with much smaller numbers, and decrease the actual effect on the taxpayers, the size of an organization you require.

We should not quit doing the real state-of-the-art technology development. Those are things that you can support at institutions of special excellence, whether it be Pitt or CMU or PETC or whatever. There are a lot of places that can get a lot of miles out of relatively small numbers, but when we get off into you worrying about the priorities of demo plants and semicommercial plants and $400 million pilot plants and $2.5 billion demo plants, you know sooner or later you just have to fold up.

You are not going to get there. You do not need to deal with such big numbers to do the thing that is probably the most important for this committee to really be interested in; that is, science and technology. You know project developments start getting very expensive, and you really ought not to go into project development until economics does come to bear.

In the initial science-technology development, state-of-the-art sort of things, you do not worry about payout all that much. You just worry about high risk, maybe long-range potential, learn something significant. These are not specific programs.

A good program at a university can do wonders with $50,000 a year, but you are spending $50,000 an hour on some of these pilot plants.

Mr. **Ertel.** I understand what you are saying, but I would like to take you back to 1973.

If we had that philosophy, and we did, we saw oil prices triple in this country because of an embargo. We saw ourselves in a position that if we had been in a confrontation like the Falkland Islands or had been involved in a Middle East war, we would not have had the wherewithall to sustain our war machine.

How do you explain that, and how do you work that into your equation?

Mr. **Sudbury.** All I am saying is the thing we tried to do starting in 1973 did not work. We have not produced one Btu out of the ERDA and DOE programs. We spent more money than the sum total of the profits of the top 20 oil companies in the country during this period of time, and we have not produced any Btu's. That system did not work.

Mr. **Ertel.** The gentleman-next-to-you's testimony seems to contradict that to some degree. He talks about the fact that he did a fluidized bed project that probably would not have gone without Federal funds at the developmental stage.

Mr. **Sudbury.** It would not have gone if Conoco had not put $5 million up to build it.

Mr. **Ertel.** Pardon?

Mr. **Sudbury.** If Conoco would not have put $5 million up to build it, it would not have gone. Fluid bed combustion would have gone. There are 5 or 6, or 7, or 8 candidates that would go. This one went and got off into a lead because private industry paid a bill, $5 million, to make it go, and we are using up 50 people every day now to debug it, and you know we are as enthused about the whole thing as he is.

Mr. **Ertel.** I thought I read Dr. Ray's testimony——

Mr. **Sudbury.** He made a statement of the key role of the Government in there. I heard it. How key it was I do not know, but the real key was when it went to big money, private industry had to do it. In the early stages the Government ought to be involved.

Mr. **Walgren.** If I could ask if I just might, at this point, Dr. Ray, you said in your testimony that considering the nature of the coal industry today, it is unlikely that the free market will naturally stimulate the development of new process technology for coal conversion. I kind of take that to mean that because of the long lead times that we are talking about, there is this gap between proof of concept and application.

Can you develop that for me?

Dr. **Ray.** Yes.

I think that is true. I think that there is a spectrum of different beneficiaries, and these are not necessarily the producers, or the providers of the equipment. I think perhaps the Stevenson-Wydler Act of a year or two ago set up a framework for cooperative technology. If that can be implemented in some ways that give the industry a stronger or a more major role in the funding of the research under the current tax laws, then cooperative technology between the industry groups can and will help to fill that gap.

We find in other areas that we can put together programs which we call industrial group programs, where we bring together a number of different industrial companies, maybe from different industries, on a particular piece of technology. This is a way to fill that gap, where no one of those industries can make the total investment at that stage, but many companies together can make the investment.

There is a question of the antitrust laws in some cases, as you bring out, but in general these programs are open to everyone, so there are not antitrust problems.

I would like to comment, relative to the fluidized bed, that I think both sides of that argument are correct. The Department of Energy's investment, at the time that investment was made, was very critical. Had that investment not been made, the technology would not have reached a point where Conoco could have picked it up. Now true, there may have been other fluidized bed technologies that would have been there at the time, but that particular technology would not have been ready at the time it was ready without the Government involvement.

Mr. **Ertel**. If I may just interrupt, your statement, "The ability to scale up the process was made possible with Federal support in the mid-1970's."

Dr. **Ray**. That is true.

Mr. **Ertel**. That is a scale-up process. That is up to what, demo plant?

Dr. **Ray**. No; it was up to pilot plant. The step from pilot to demo was by Conoco.

Mr. **Sudbury**. I think we maybe do not even need to argue on this. I think you really are making the very point I am making.

Mr. **Ertel**. Exactly.

Mr. **Sudbury**. The injection of a very small amount of money. How much was it, $2 million, $1 million.

Dr. **Ray**. On that order; yes.

Mr. **Sudbury**. I am saying that these relatively small amounts of money done in the early stages of technology are what needs to be done to keep something from dying. I am saying once it gets to a project you have got a proven track record in the Government that you just cannot function.

You need a relatively small, selective budget that aims like a rifle at a particular point here, and they kept one moving with small money. We are not talking about billion-dollar demos here. We are talking about in a center of excellence just a few dollars to keep a program going, and that is the point that I tried to make in what I believe is the role of the Federal Government, to take some of these early, create some of these early technologies and give them a little nudge, but once they get up to a project state, the numbers get so big and so many people get involved that it just has not worked.

Mr. **Ertel**. If I may just interrupt you for a moment, but I guess to some degree we are not talking differently but I think we had better get our semantics down correctly here.

You are talking about a demo plant which is beyond the pilot plant stage, but you say the administration as I read their program is only research. They really drop out the developmental stage which I consider to be beyond the basic research stage, going to the pilot plant project, to get it into a commercially available mode where somebody can go to a demo plant or go to a commercialization.

Someone has got to meet that difference between very basic research and when you get to that demonstration phase, and if we fail in that area, we have got that technological gap, and one of you referred to that gap that somebody has got to worry about.

Mr. **Sudbury**. That is the nudge I am talking about.

Mr. **Ertel**. Pardon?

Mr. **Sudbury**. That is the nudge I am talking about.

Mr. **Ertel**. But that nudge is a very large nudge.

Mr. **Sudbury**. A very small nudge.

Mr. **Ertel**. Well, depending on whether you are talking about in research and development funds, research funds which can be fairly small, and developmental funds which are very large in relationship to research funds, and then demo, which is larger yet general.

So it depends, if we are coming from your perspective at the demo stage it may be small. Coming from the research viewpoint it is large, if I am correct in my analysis.

Mr. **Sudbury**. I am speaking of the fraction of a DOE budget of multibillions per year. We are talking about relatively small numbers to do a very effective job.

Mr. **Ertel**. It depends again on what you are talking about. If you are talking about high energy research you are talking tremendous sums of money. If you are talking about a different type research you might be talking different sums of money.

Just to build the Isabelle project on Long Island, I have forgotten how many hundreds of millions of dollars it is going to cost us just for that research facility itself. Dr. Ray, do you have any comment on that?

Dr. **Ray**. Yes. If I may use the Department of Defense terminology, it is the 6.2 or 6.3A kind of research that I see as the role of the Federal Government in the energy area. I think that as you get to demonstration plants, you are quite right. However, at the time that economic feasibility shows itself, if the technology is not there, if it has not been brought to that point by whatever mechanism, then the economic feasibility of commercialization is no good to you. You have to have the technology ready when the commercialization is economically viable.

I think I agree with both sides of the argument that the investments were relatively small in our MSFBC technology. They were critical at the time they occurred. However, it might be another several years before Conoco or someone else would have seen it as a commercializable enterprise, but the technology was ready when it happened.

Mr. **Walgren**. Dr. Williams.

Mr. **Williams**. I would like to hope that Dr. Ray would include as part of research 6.1. He was concentrating on the 6.2 and the 3A.

Most of my remarks are directed upon that end of the scale even down so far as 6, which is another classification I personally use. It is that kind of research that I was speaking of in contrast to the development, the development and demonstration. I think you properly pointed that out, and I do not believe there is any question but just in terms of making sure for the record that we are talking about research in my context with 6.1, 2, 3A as compared to development which is the demonstrations.

I love to compare the total 6.1, 2 and 3A in the Department of Defense in terms of how many B–1 bombers that is. Take the whole 6.1, 6.2 and 6.3A program, and equate that to one or two of the big bombers.

Dr. CHUN. I would like to mention that in certain technology areas, where the capital, the investment is extremely capital-oriented, certainly Dr. Sudbury's problem is a real problem. Now how much capital investment can a corporation afford to make.

On the other hand, there are many technologies that both the Federal Government and the private sector work together on. Now, in some technologies where the capital investment is not so intense, I think I can give you many examples of good cooperation and very beneficial results.

As I mentioned, coal-oil mixture and coal-water mixture, now there the little bit of Government funding created a tremendous interest in the private sector, we had about four technology transfer meetings and the response has been tremendous, both in the United States as well as abroad.

They are being commercialized, so I do not think this can be sold by one sector, whether it is the Federal sector or private sector, but by working together, as Dr. Williams was suggesting, I think we can make a go of that.

Mr. ERTEL. You talked about the coal-oil mixture and I noted you said it would be a savings of 15 percent over existing utilization of oil. Has there been anyone utilizing coal-oil mixtures in utility plants at the present time and if not, is it because there is a need for conversion of the technology or the equipment, the boiler equipment, the burning elements or what?

Dr. CHUN. There are some plans on the part of the utilities to look at coal-oil mixtures. An example, Florida Power & Light have plans to make use of coal-oil mixture, and in Japan we are very, very active in commercialization opportunities for the coal-oil mixture program. That is another example of what Dr. Williams was mentioning.

Only 4 years ago a Japanese delegation came to PETC and they got a briefing from us on our technology and now they are in the process of actually building a utility boiler based on coal-oil mixture. Certainly since we are working on a coal-water mixture program, which I believe to be a more advantageous technology, there are some people in the private sector who would like to wait and see before they can make the choice between the two.

That is quite understandable, but yes, sir, there has been a very close working relationship with industry from our point of view, and it is moving ahead, yes.

Mr. ERTEL. That is a curious phenomenon. Here we have the Japanese going to commercialize it, probably be in the international market selling that technology, and we are sitting back waiting to see whether the coal-oil or coal-water mixture will be the more economical, and probably I would suspect that the coal-oil mixture commercialization, probably to a great degree will probably influence the coal-oil or coal-water commercialization as well as far as the technology is concerned.

Mr. SUDBURY. We are probably going to end up very, very smart having waited on the coal-water mixture.

Mr. ERTEL. That is a judgment call.

Mr. SUDBURY. I realize it is.

Mr. ERTEL. What do you think of that, Dr. Williams?

Dr. WILLIAMS. That is out of my knowledge.

Mr. ERTEL. That was a good pass.

Mr. WALGREN. For lack of strategic planning.

Dr. WILLIAMS. Plus the fact that I am in aerospace.

Mr. WALGREN. I wanted to ask whether the right people are talking to each other. It was mentioned that while we are all three here, universities, government, and industry, but somehow or other you cannot come away from looking at how other countries are doing better in putting on line new and clearly successful technologies, without thinking that the right people in our country are not talking to each other.

Dr. CHUN. I know I believe that there have been many opportunities where all the right people got together and discussed the matter. When it comes to the investment decision, I think with all the proper information that you have at hand, the private sector will have to make their investment decisions, so the lack of making that decision does not necessarily mean that the interaction was lacking.

To give you an example, I am going back to the coal oil mixture situation, 4 years ago when we started the coal oil mixture program, as a research project, there was the first international symposiums that we sponsored, it was primarily amongst the researchers, including the researchers from private industry as well as academia. Now the third and the fourth symposiums that we sponsored, I could say a lot of business executives attended the meetings, and that is true from the international side also, so as the technology moves along, and obviously the opportunities for investment become more obvious, we attract a tremendous number of business executives to these conferences, and we had a very good working relationship.

Another example is, as you know, we are shutting some of the demonstration projects, shutting them down in coal liquefaction, and we as the lead laboratory in coal liquefaction have the responsibility to manage all those data bases that we generated.

What we want to do is to have private industry and academia participate in the management of those technical data bases, so we established a task force to have private industry and academia all participate with the Government, and try to put this information in the form that our future users can use.

Now we have a very active program along this line, and we asked different industries, such as A&E's, resource suppliers and refiners and all these industries that are participating with us to try to develop a system so that when the time comes the information will be stored and will be available to those industries who will need them, so there are a lot of interactions between the Government and the private sector.

It is just a shame that our economic system is such that all the technologies that we develop cannot be commercialized right away. If we are not doing enough of a job in making interactions with industry, certainly we will try our best to improve that.

Mr. **Walgren**. I think that is all to the good, and I do know that there is a lot of interaction between industry, and I know that they are there to pick up these things when they are ready to be picked up, and when they become economical, and they will not be picked up before then.

What concerns me is that whether bringing things through proof of concept stage is sufficient for this system as we now see it to bring our future technologies along at the earliest practical moment. Could I get a reaction to that question briefly from each, limiting yourself to proof of concept stage, which is apparently the present philosophy.

Dr. Ray.

Dr. **Ray**. Yes. I think our experience with U.S. industry in the last 3 or 4 years, and particularly in the last 2 years, shows us that the hunger for new technology is just almost exploding, so I would tend to be very optimistic that in the future bringing it to the proof of principle state is probably a more viable situation than it has been in the last 5 to 10 years.

I see the industry's interest even in very severe economic times. The increase in industrial expenditures in R&D, in the development and commercialization of technology, seems to be going far beyond what I would have anticipated looking ahead from 3 years ago. I am very optimistic that bringing it to that stage might be even more useful to us now than perhaps it has been in the last few years.

Mr. **Walgren**. Dr. Sudbury.

Mr. **Sudbury**. I guess my comment comes a little bit differently. I spent 10 years trying very, very hard on a number of these large projects with the Government where if you meet these criteria we will build a large CO_2 acceptor plant. We will build a slagger in Noble County, Ohio, and so forth. I guess by difference I have concluded that that system, once the numbers get big, just cannot operate, so the only system we have left is really for the private sector to build these things, and I am on your side, all our sides, that this nudge to early stage technology is a very desirable thing, and it is the best that we can do right now.

Mr. **Walgren**. You know what concerns me is that I am afraid that we have a very important and bad past 5- or 10-year experience to evaluate as to the role of the Government would would serve the country best, and I think you are absolutely correct in saying that these large projects soaked up a lot of money that could have gone for a lot of——

Mr. **Sudbury**. Canceling a lot of state of the art-type projects.

Mr. **Walgren**. And yet I cannot get out of my mind that we were essentially asked to jump out of a window and invent a soft landing device on the way down. As you said in your testimony, Dr. Sudbury, at a certain point in time those major projects even on their scale looked to be what was indicated as economically supportable.

Mr. **Sudbury**. Absolutely.

Mr. **Walgren**. But the change in those oil prices which were not within our national control changed all that, and I guess I just hope we in our reaction to the difficulties of dealing with those large projects, and also with the disappointment that we have because they are obviously now not critically needed in the next year and a half to 3 years, I just hope that we do not overreact to that reaction.

Mr. **Sudbury**. The alternate system of the Synthetic Fuels Corporation to do this role of things has not been mentioned here today, and I guess at least it ought to be considered.

The jury is still out on what that will really accomplish, but at least they have tried to eliminate some of the worst barriers in the DOE system for carrying out big projects, and essentially saying if you can meet the right criteria, we will be supportive. Whether any of these are going to be built or not, a lot of the weaknesses of the DOE system for large projects have been cleared up in synfuels corporation, and you know it is going to be another 3, 4, or 5 years before we know how that comes out, but hopfully at least 1, 2, or 3 of these projects will be built.

Mr. **Walgren**. Let me ask Dr. Chun, we now have 328 full-time employees at the Pittsburgh Energy Technology Center.

Dr. **Chun**. Yes.

Mr. **Walgren**. And what are the projections for the near term future?

Dr. **Chun**. Since we are a Federal laboratory, our future is very closely tied to our Federal budget. Until the Federal budget is finalized, it is very difficult for me to give you a precise answer, but based on the Presidential budget submission, and a request for $107 million for the fossil energy program in 1983, the OMB input to our manpower ceiling was 511 for the entire fossil energy program.

Now we are using, based on that manpower ceiling, 206 as the planning number in looking at our 1983 manpower situation. Now if the budget process comes out such that the budget for 1983 is different from $107 million, certainly those numbers may change, but at the moment we are making plans based on 206.

Mr. **Walgren**. For a one-third cut?

Dr. **Chun**. That is the planning number we are using, if the budget becomes $107 million.

Mr. **Walgren**. Let me ask about the dollars on research both within the Center and contracted out.

You indicated that you are at $13 million in 1982, within the center, inside the center, and you are at $300 million in terms of research which you administer outside the center. What would the comparable numbers be under the Presidential submission?

Dr. **Chun**. Let me clarify that point a little bit. Our annual budget for the entire facility here, that includes the contracts as well as in-house R&D and other expenses here, they come to approximately a 3-year average of about $100 million. Now for some contract projects, due to the previous year of funding and so forth, you add them all up and it comes to about $300 million.

Now in terms of annual budget, if the 1983 budget for the total fossil energy becomes $107 million, and if the breakdown of that for those programs that PETC is involved in that we manage becomes much smaller, certainly our management share will become smaller, so when our total share becomes smaller, then our inhouse R&D share will have to be reduced in some manner that we will have to decide at that time.

Unless the total 1983 budget is finalized, it is very hard to figure out what the breakdown of that budget will be for those programs that we are involved in.

Mr. WALGREN. But projecting based on $107 million, even not distinguishing between what is done inside and outside, what would be the impact of the $107 million on the coal research effort that you are supervising?

Dr. CHUN. Currently the 1982 budget for fossil energy is a little over $400 million, so the reduction of the budget from $400 million down to $100 million certainly will have a dramatic effect on us.

Mr. WALGREN. It could be as much as a three-quarters reduction in the coal research effort, is that correct?

Dr. CHUN. If $107 million is passed, yes.

Mr. WALGREN. I think this is one of the important things that we could take away from here, in fact this is some direct realization of how deep the projected reductions are, because you hear at various times the thought that we are not reducing our efforts in various areas. I think it is pretty important that we understand the overwhelming size of that reduction.

Mr. ERTEL. Will the gentleman yield for a moment?

Mr. WALGREN. I will be happy to.

Mr. ERTEL. Let me ask you, Dr. Chun, let's assume for the moment we pass the $107 million budget and you had to take a three-quarter cut, a 75-percent cut in your allocations for this center. What would be some of the type projects you would be cutting out?

Dr. CHUN. That depends. When we have a budget reduction, obviously that reduction will be broken down into different programs. For example, I am sure that about 80 percent of the fossil energy program will be in the coal technology area. Based on a $107 million proposed budget, the overwhelming majority of that budget will be the coal budget.

Then what will happen to the oil program, the gas program, and the shale program? These are different programs that make up the total fossil energy budget, so that is the reason why I emphasize that depending on the budget and depending on the breakdown of that budget, that will determine the coal program.

Now if the budget becomes $107 million, a reduction from $400 million this year, no matter how the breakdown comes out, certainly the effect will be serious.

Mr. ERTEL. Let's assume for a moment that that cut was across the board. In other words, we took 75 percent off each program, which probably is not realistic of course, but what would be the type of projects you would start to cut out? Where would your priorities be? Which ones do you give the least priority to that you would be cutting out?

Dr. CHUN. The highest priority program within DOE is still the liquids program, since that is where our energy shortage is, so our highest program priority is in the liquids program. For that reason

I think coal-liquefaction or liquids-oriented programs will remain strong, relatively strong within that budget.

Other programs that will supplement liquid fuel supplies such as coal-water mixture, I think they will remain strong in that program. However, these are all relative percentages that I am talking about, so the actual total absolute sum will be certainly reduced quite a bit, but the highest priority is in the liquids or liquids supplemental programs.

Mr. **Ertel**. Things like the cleaning process would be the ones that would be eliminated first is what you are saying I guess.

Dr. **Chun**. They may receive lower priorities, yes.

Mr. **Ertel**. And is your liquefaction budget and your utilization there, is that the most costly anyway as far as the proportion of your budget?

Dr. **Chun**. That is right.

Mr. **Ertel**. So therefore you would be almost canceling everything else out to keep the liquefaction program going, because it is so expensive as a project?

Dr. **Chun**. At a $107 million budget, in fact even at a $400 million budget we have already cut out what we call capital-intensive programs anyway, so from here on basically our program is a long-range, high risk, and basic research type.

I do not think that we will cut out any more large-scale operations, because we do not have much of a large-scale operation at this point.

Mr. **Walgren**. Whether or not a program is capital intensive is sort of an arbitrary characteristic?

Dr. **Chun**. That is right.

Mr. **Walgren**. That does not have very much to do with its contribution to our future. I guess what is troubling me is that I see a lot of arbitrary reductions. I keep getting this feeling that people sitting around a table can figure out what works, what is practical, what is pragmatic, and yet with the overlay of polarized approaches to Government that we are presently experiencing, we seem to be failing miserably at getting the right people sitting around the table.

From my own perspective as chairman of another subcommittee that has to do with NSF, I think it is ominous to note that for the first time in our history, we have had totally party-line votes on funding for the National Science Foundation, without one Democrat joining the Republican view or without one Republican joining the Democratic view, and how sad that is. I just hope that as we all sit down to try to realize where we are, that the proper lines of communication will open up, because if we approach this either arbitrarily or from some ideology, we do the country a great disservice in my view.

Anything further, Allen?

Mr. **Ertel**. One other question.

I am concerned about this 122-person cut that you may have. If that were to take place, what happens through the bumping system? I assume you have a seniority process here.

It seems to me that you would have people working on one project who might be able, because they have more seniority, to bump somebody in another project and you would have bumping on down the line, and you would have people working in areas which they may have originally been qualified for by education but have not been working in that area for 10, 15 or maybe even 20 years, then bumping back into another area because they want to retain a job.

Is that a possibility, and will we have people so confused within the structure here that we will have people working on projects that they had not worked on before even though they had the basic educational requirements like I did for engineering 20 years ago. I am sure I could not design a fluidized bed plan at the present time.

Is that a possibility that you would have that kind of activity with this downward bumping system?

Dr. CHUN. Well, the bumping system is a Federal law, and every time we have a reduction in force, certainly we have rules and regulations that we have to follow.

Now before we get to that point, when we have drastic changes in our budget, I think we would have to sit back and figure out the best program mix that our laboratories should have in line with the policies that have been developed, so at that point we would have to decide on not only the program mix but the people mix as well.

Then when that is done, we will have to go into a reduction in force situation. Then our bureaucratic process of handling that will include a bumping process.

Mr. WALGREN. Is it not true, Dr. Chun, that if you took your organization and said OK, we are going to cut that 75 percent in funding, we are going to fire one-third of the personnel and we are going to move everybody around through areas of expertise, at some point you are going to reach a level where we are just throwing the money away and the whole thing ought to be just plain stopped?

Dr. CHUN. I certainly hope we do not come to that situation.

Government managers have extra-difficult responsibilities to carry out as you know. I was with private industry before I came here, and I know how they manage, and I know how they handle problems such as a reduction in force. I also know how they handle their R&D activities as well.

We are not in that kind of a situation.

To give you an example, in private industry, if the technology becomes a success, that is the beginning of a very prosperous R&D program. In our Federal laboratories, if the technology becomes a success and the private industry is not willing to take over, that is when we move away from our technical success and we learn to cope with this kind of a situation. It is a very difficult thing to come up with new idea after new idea every time you have a technical success.

Similarly, we have a different situation in reducing the number of people we have. I think in private industry the situation is much simpler than in the public sector. However, we have gone through this process ever since 1953, and I think in our audience we have our former director here, who spent many years during the times when the budget was extremely low. We found that some of the most creative work that this station or this Nation did in the past was accomplished during that period of time, and I certainly hope that I can handle that job.

I am sure that we will handle that. It is a difficult management role, but we will do our best.

Mr. WALGREN. From everything I know, it could not be in better hands. It is fair to say that this kind of effort has never experienced this kind of massive reduction before, is that correct?

Dr. CHUN. I was not here in the 1953 time period, but from what I heard we had many, many ups and downs.

Mr. WALGREN. But do you recall a three-quarters cut in funding?

Dr. CHUN. No, I do not.

Mr. WALGREN. Thank you very much, gentlemen.

You have been a good panel. We did not even get to the ideas about science manpower that each of you alluded to in different ways. I just again hope that we try to get the right people talking to each other in the right forums and with the right open minds to try to support the investment for our future that this country needs, and there are very real signs though that is not happening. Thank you very much.

I appreciate your contribution.

Mr. WALGREN. The next panel is made up of Ulrich Merten, of the Gulf Research & Development Corp., along with Mr. John Murphy with the Bureau of Mines here in Pittsburgh, and Dr. Charles Hosler, dean of earth and mineral science at Penn State University. We were going to have C. J. Baroch, who was representing Babcock & Wilcox. Mr. Baroch is unable to be with us. Mr. Baroch's testimony will be made part of the record nonetheless, and will appear in full.

With that let me ask Mr. Merten to proceed first. Again, written statements will be made part of the record, and any variation that you would feel more effective is fine, but we are pleased to have you, and pleased to have your testimony.

STATEMENTS OF ULRICH MERTEN, VICE PRESIDENT, CHEMICALS AND MINERALS, GULF RESEARCH & DEVELOPMENT CO.; JOHN M. MURPHY, BUREAU OF MINES; DR. CHARLES HOSLER, DEAN, EARTH AND MINERAL SCIENCE, PENNSYLVANIA STATE UNIVERSITY; AND DR. WILLIAM SPACKMAN, DIRECTOR, COAL RESEARCH CENTER, PENNSYLVANIA STATE UNIVERSITY

Mr. MERTEN. Thank you, Congressman. I will abbreviate the written statement, if I may. My name is Ulrich Merten, with Gulf Research & Development Co., which is a unit of the Gulf Oil Corp. We employ here in the Pittsburgh area approximately 1,800 people doing research and development on a variety of energy technologies, including coal.

We are located here in Pittsburgh because this is in a coal-producing region, and Pittsburgh is an internationally recognized center of coal research. It has achieved this status in considerable measure because of the excellent work done over the years here at the Pittsburgh Energy Technology Center. Our presence in this city has made it possible to work with the center and to develop close working relationships with Carnegie Mellon University, the University of Pittsburgh, and Pennsylvania State University, all of whom are active in coal research.

The reputation and value of this area is further enhanced by the presence of the Bituminous Coal Research Group and of industrial companies with strong coal research programs, including United States Steel, Dravo Corp., the Koppers Co., Conoco, ourselves, and other companies.

As has already been mentioned in the charter of these hearings, coal is the Nation's most abundant fossil energy resource. It is well known that we are consuming more petroleum than we produce, and that we are dependent on imports for a substantial part of our petroleum requirements. We believe that the current oil glut is temporary and that real shortages of oil can and probably will occur before the end of the century unless we take adequate measures to shift our fuel consumption patterns. For these reasons it is essential to our national interests to utilize coal as a replacement for a large proportion of the petroleum now being used.

There are many obstacles which must be overcome in substituting coal for oil. Coal is a solid, and most current applications for fossil fuels require liquids or gas. Much of our eastern coal is too high in sulfur to meet environmental requirements. Our western coal, although generally low in sulfur, must be transported long distances to reach major markets. We have many reserves which are too deep to be mined economically, or which exist in inclined beds and pose difficult mining problems. Research and development have been started to solve these technical problems, and a number of promising concepts have been developed. But much more research and development will be needed as we move toward a coal-based energy economy.

We at Gulf have an active R&D program related to coal utilization, a substantial portion of which has been supported by the Department of Energy. Two specific areas in which we are active are underground coal gasification and direct coal liquefaction.

The SRC–I process for converting coal to a clean, low-sulfur, low-ash solid fuel, and the SRC–II process for converting coal to low-sulfur liquids were both invented at our Merriam, Kans., laboratory. Currently, that laboratory is performing research under a DOE contract aimed at improving direct coal liquefaction processes. Here at Harmorville, we have operated a 1-ton-per-day direct coal liquefaction unit to evaluate coal feedstocks, explore process variables, and obtain design data for commercial-scale plants. We have also carried out a number of related projects aimed at developing process and design improvements and at utilizing the products efficiently and effectively. This work has demonstrated that the process chemistry is technically sound, and that numerous bituminous coals are suitable feedstocks.

Gulf has recently completed several tests in Rawlins, Wyo., of underground coal gasification as applied to steeply dipping coal seams. We have shown that it is technically feasible to recover energy from these ordinarily unminable resources, and believe that this may, in fact, be the least costly gasification method known. We have also shown that the process is flexible, and have every indication that the environmental impact can be kept to an acceptable level. Both low- and medium-Btu fuel gas can be produced, and the latter can be converted to synthetic natural gas, to methyl fuel, and to hydrocarbon liquid fuels by known technologies.

Neither have yet become commercially available. This is fundamentally so because, while their projected costs are competitive with the cost of imported crude oil, the uncertainties in that price and in the technologies are too great to permit private investment on normal commercial terms. As a Nation, we have powerful incentives to reduce the economic and technological risks and to drive down the cost of alternative fuels. We can reach this goal only through further development of appropriate technologies. And there are many frontiers yet to be explored.

The industry, the universities, and the Federal Government all have a role to play in this research effort. We believe that a continuing Federal involvement in high-risk coal research is of great importance.

We would suggest giving priority to fundamental research conducted by academic researchers in a teaching environment. Such research serves the dual roles of building our knowledge base and enlarging the pool of skilled technical people which Government and industry can draw on as coal becomes an ever more important resource.

We would suggest also emphasizing high-risk, exploratory research efforts led by organizations with a direct interest in commercialization. Particularly in the case of technologies like underground coal gasification, this work cannot always be done at the laboratory bench and may, therefore, be more costly than most academic efforts. But it is the steppingstone to better processes, and more likely to be fruitful if carried out in a commercially oriented environment.

Much has been said in recent months on the subject of the Nation's climate for innovation, the importance of cooperation between the universities and industry, and the Federal role in encouraging such cooperation. In our experience, we have found it of great value to have our own people participate as active contributors to academic research projects being conducted in university laboratories and to have academic advisers as part of the teams engaged in our exploratory research activities. The two-way flow of information which occurs is of inestimable value to all participants.

I expect that today's hearings will illustrate that Pittsburgh industries and universities already have a good record of cooperation in the area of coal research; and that the Federal Government, acting through the Pittsburgh Energy Technology Center, has played and is playing an important role.

Thank you very much for this opportunity to express our views on the coal research program.

[The prepared statement of Mr. Merten follows:]

STATEMENT OF ULRICH MERTEN, VICE PRESIDENT, GULF RESEARCH & DEVELOPMENT CO., GULF OIL CORP.

Gulf Research and Development Company is a unit of Gulf Oil Corporation. We have a staff of 1600 employees of whom about half are professionally trained. Our primary mission is to perform research and development to support Gulf's business activities. This R&D is directly related to petroleum exploration, production, refining and products, to chemical manufacture, and to the production and utilization of oil shale and coal.

Gulf Research and Development Company is located in Harmarville, Pennsylvania, right here in the Pittsburgh area. Pittsburgh is part of a coal-producing region and is an internationally recognized center of coal research. Pittsburgh has achieved this status in large measure because of the excellent work done over the years at the Pittsburgh Energy Technology Center. Our presence here has made it possible to work with the Center and to develop close working relationships with the University of Pittsburgh, Carnegie Mellon University and Pennsylvania State University, all of whom are active in coal research. The reputation of the area is enhanced by the presence of the Bituminous Coal Research Institute and of industrial companies with strong coal research programs, including U.S. Steel, Dravo Corporation, the Koppers Company and ourselves.

As stated in the charter for these hearings, coal is the nation's most abundant fossil energy resource. It is well known that the nation is consuming much more petroleum than it produces and that we are dependent on imports for a substantial portion of our petroleum requirements. Also, it has become quite difficult and expensive to locate new, large, domestic petroleum reserves, and production costs are generally high for both new reserves and enhanced recovery from old reserves. Our high dependency on foreign oil places us in a vulnerable position in the event of national emergencies and has a serious adverse effect on our balance of payments. Political factors over which we have little or no control have a large influence on the price we pay and the availability of supplies. We believe that the current oil "glut" is temporary and that real shortages of oil can and probably will occur before the end of the century, unless we take adequate measures to shift our fuel consumption patterns. For these reasons, it is essential to our national interests to utilize coal as a replacement for a large proportion of the petroleum now being used.

There are many obstacles which must be overcome in substituting coal for oil. Coal is a solid, and most current applications for fossil fuels require liquids or gas. Much of our Eastern coal is too high in sulfur to meet environmental requirements. Our Western coal, although generally low in sulfur, must be transported long distances to reach major markets. Many of our reserves are too deep to be mined economically and some of the reserves are in inclined beds, which pose difficult mining problems. Research and development has been started to solve these technical problems and a number of promising concepts have been developed; but much more R&D will be needed as we move toward a coal-based energy economy.

Gulf has an active R&D program related to coal utilization, a part of which is supported by the Department of Energy. Some of the specific areas in which we are active are underground coal gasification, direct coal liquefaction, coal cleaning, coal characterization, and coal resource assessment.

The SRC–I process for converting coal to a clean, low-sulfur, low-ash solid fuel and the SRC–II process for converting coal to low-sulfur liquids, were both invented at our Merriam, Kansas, laboratory. Currently, that laboratory is performing research under a DOE contract aimed at improving direct coal liquefaction processes. Here at Harmarville, we have operated a one ton/day direct coal liquefaction unit to evaluate coal feedstocks, explore process variables, and obtain design data for commercial-scale plants. We have also carried out a number of related projects aimed at developing process and design improvements and at utilizing the products efficiently and effectively. This work has demonstrated that the process chemistry is technically sound, and that numerous bituminous coals are suitable feedstocks.

Gulf has recently completed several tests in Rawlins, Wyoming, of underground coal gasification as applied to steeply dipping coal seams. We have shown that it is technically feasible to recover energy from these ordinarily unminable resources, and beleive that this may, in fact, be the least costly gasification method known. We have also shown that the process is flexible and have every indication that the environmental impact can be kept to an acceptable level. Both low- and medium-Btu fuel gas can be produced and the latter can be converted to synthetic natural gas, to methyl fuel, and to hydrocarbon liquid fuels by known technologies.

Gulf is also interested in the utilization and application of coal as a solid fuel. We are currently undertaking a DOE-funded study with Combustion Engineering to test the use of coal in oil-fired boilers. The coal will be fed to the boilers as finely divided particles suspended in water. If this technology can be developed to attain satisfactory combustion performance, it would permit the direct substitution of coal for petroleum in many existing power plants with a minimum of retrofitting.

None of the technologies to which I have referred has yet become commercially viable. This is fundamentally so because while their projected costs are competitive with the present price of imported crude oil, the uncertainties in that price and in the technologies are too great to permit private investment on normal, commercial terms. As a nation, we have powerful incentives to reduce the economic and technological risks and to drive down the cost of alternative fuels. We can reach this goal only through further development of appropriate technologies. And there are many frontiers yet to be explored.

The organic portion of coal is a very complex mixture of hydrocarbons with compounds of oxygen, sulfur, and nitrogen. The ash or inorganic portion of coal is also very complex, and its composition strongly influences the behavior of the organic portion. The composition of coal also varies greatly with geographical region. Due to this complexity, research workers have only a partial understanding of the chemical composition of coal and of the chemical reactions which coals undergo when processed. A much better understanding of coal chemistry is needed to provide the basis for future process improvements.

Several direct coal liquefaction processes have advanced to the stage where demonstration-scale facilities could be built; but we believe that further advances can be made through R&D on a much smaller scale that will lead to processes significantly better than the existing ones. At Harmarville, we are studying such subjects as the behavior of the oxygen compounds in coal during processing, and the mechanism of hydrogen transfer, an important reaction in direct coal liquefaction. At the Merriam laboratory, we are seeking to improve the yields of desirable liquid product, reduce processing costs, improve product quality, and extend the resource base of coals suitable for converting to liquids. Over the last several years, we have identified disposable catalysts suitable for promoting the liquefaction of bituminous coals. We have also used disposable catalysts to obtain high liquid yields from certain Western coals ordinarily thought of as having poor reactivity. We are continuing to test other ideas for process improvements and expect that liquid yields can be increased substantially through such research.

As stated previously, underground coal gasification of steeply dipping beds has been shown to be feasible in small field tests. This research needs to be continued to show that gas of satisfactory quality can be produced efficiently over a long period without adverse environmental effects. We also believe that there is much to be gained through continued theoretical studies of underground coal gasification systems. Such studies, when used as a step in process development, serve to identify optimum conditions, reduce the test work required, and identify tests that will be of greatest value.

There are many other potentially fruitful areas of R&D that could be pursued to facilitate the use of coal. For example, although coal cleaning is in commercial use to reduce sulfur and ash content, we do not know how to remove the organic sulfur except through liquefaction or gasification. Better means are needed to transport coal over long distances. Further advances are needed in combustion of coal to improve efficiency and control waste products. Surface gasification of coal is expensive and advances are needed to permit economical manufacture of synthetic gas for use as fuel and for conversion to liquid fuels by indirect coal liquefaction.

Industry, the universities, and the federal government all have a role to play in this research effort. We believe that a continuing federal involvement in high risk coal-related research is of great importance.

We would suggest giving priority to fundamental research conducted by academic researchers in a teaching environment. Such research serves the dual roles of building our knowledge base and enlarging the pool of skilled technical people which government and industry can draw on as coal becomes an evermore important resource.

We would suggest also emphasizing high risk exploratory research efforts led by organizations with a direct interest in commercialization. Particularly in the case of technologies like underground coal gasification, this work cannot always be done at the laboratory bench and may, therefore, be more costly than most academic efforts. But it is the stepping stone to better processes and more likely to be fruitful if carried out in a commercially-oriented environment.

Much has been said in recent months on the subject of the nation's climate for innovation, the importance of cooperation between the universities and industry, and the federal role in encouraging such cooperation. In our experience, we have found it of great value to have our own people participate as active contributors to academic research projects being conducted in university laboratories and to have academic advisors as part of the teams engaged in our exploratory research activities. The two-way flow of information which occurs is of inestimable value to all participants.

I expect that today's hearings will show that Pittsburgh industries and universities already have a good record of cooperation in the area of coal research; and that the federal government, acting through the Pittsburgh Energy Technology Center, has played an important role in supporting and enhancing that cooperation. There is every reason to believe that the nation as a whole can continue to benefit from this three-way interaction.

Mr. WALGREN. We appreciate that very much, Mr. Merten.

Next, Mr. Murphy.

Mr. MURPHY. Mr. Chairman, I am John Murphy, the research director of the Bureau of Mines, Pittsburgh Research Center, and I am pleased to appear before you today to present a brief overview of activities and accomplishments at the Pittsburgh Research Center, but first by way of introduction let me briefly outline the mission of the Bureau of Mines. I do this, primarily, to distinguish the role of the Bureau of Mines from other agencies such as the Department of Energy which are also involved with aspects of the minerals/energy problem.

The Bureau of Mines is located in the Department of the Interior. The major themes of the Bureau's mission have been defined by the Bureau's Director, Mr. Robert C. Horton, and are enumerated in the statement submitted to the committee.

The Pittsburgh Research Center conducts work in support of a number of the Bureau themes; however, it is the leading Bureau of Mines research center involved in the work pertaining to "health and safety practices in the minerals industry." Of necessity, the Bureau's involvement in coal mine health and safety requires that the Bureau be cognizant of coal productivity concerns. It is the Bureau's objective to have its technological developments (aimed at improving health and safety) freely accepted by the industry. To insure this transfer, Bureau researchers must be mindful of the impacts of their work on mine productivity.

PRC PROGRAMS—HEALTH AND SAFETY

PRC is the only Bureau of Mines facility that is involved in all aspects of the mining health and safety problem. The center structure reflects this complete involvement, and the specific research and development groups are identified in the prepared text. In order to convey to you the technical quality and the scope of activities of the center, I have selected to discuss with you today some recent technical accomplishments, and there are additional ones in the prepared text submitted to the committee.

The first example pertains to dust control and ventilation. Notable progress has been made in the control of respirable dust at working faces, but the problem has not been completely solved. Respirable dust problems specific to longwall mining are currently being addressed by an integrated Bureau program with the support and assistance of the mining industry and DOE. One example of a PRC-developed longwall dust control technique is the "shearer-clearer" which has demonstrated its effectiveness in reducing the coal dust exposure of longwall shearer operators. The longwall shearer machine shown in the photograph before you cuts coal using a drum located a few feet upwind of the operator, and some of the cutting dust normally passes over the operator. The "shearer-clearer" shown in this photograph is an airstream diversion system that moves the dust cloud away from, and around, the operator, thus reducing personal exposure. This dust cloud diversion is accomplished by simple realinement of the water sprays already installed on the shearer as a dust suppression aid. As a result of our research and development in this area, approximately one-third of operating longwall faces operating with double drum shearers currently use a version of the shearer-clearer system.

Temporary roof support systems. Setting of mechanical jack or wood posts under unsupported roof accounts for about 20 percent of all roof fall fatalities. Automatic temporary roof support (ATRS) systems can eliminate the need for mine personnel engaged in roof support to work under unsupported roof. An ATRS system has now been developed by PRC for single, fixed-head roof bolting machines used in low coal mines, defined as less than 42 inch seam thickness. It is transported underground, as shown by the photograph, on the bolting machine drill head, using a special steel sleeve attached to the bottom center of the beam. The ATRS was adapted to a roof bolter for 5 months of underground evaluation in the production cycle of Imperial Colliery Co. Mine No. 20, in Burnwell, W. Va., as shown in the photograph. The ATRS was preferred, by the mine's bolting crews and by MSHA, to mechanical jacks for safety, ease of installation, and time saving. The ATRS is now part of the MSHA-approved Mine No. 20 roof control plan and is currently used in coal production. The prototype ATRS design can be retrofitted to any fixed-head roof bolting machine used in U.S. low coal mines.

Explosion-quenching barriers. Recent mine disasters which involved explosions of coal dust have emphasized the need for additional protection against explosions propagating through mine roadways. PRC research has demonstrated that such protection can be provided by barriers, one of which you see in the picture before you, consisting of troughs filled with various quenching agents released into the oncoming explosion. Here is one photograph from a high-speed framing sequence showing how that release is accomplished. Currently, 50 such troughs seen in this photograph have been installed in an operating mine complex. Full-scale explosion tests with other barrier types and arrangements are continuing at the Bruceton facility, and installations are planned at other working mines on a voluntary basis.

Nonincentive sheathed charge. Occasions arise in mining where large rocks, such as loose hanging roof slabs, need to be dislodged or shattered but where access to the rocks in order to break them mechanically or drill boreholes for explosives is difficult or dangerous. In nongassy mines this problem can be solved with explosive charges, using a process commonly called mudcapping, but in coal mines mudcapping is prohibited because of the high probability of a mine gas ignition. PRC has recently developed an explosive charge with an integral sheath of ignition-inhibiting material, which can be fired safely in flammable atmospheres. This charge has been successfully tested both in the laboratory and in the field to verify that it does not ignite natural gas or coal dust/gas atmospheres.

Here you see a photograph of the fuel experiment with the charges emplaced on a boulder. In the field tests we have successfully been able to fragment the boulder, as well as in underground coal mines to evaluate its performance. Amendment of MSHA standards to permit its use under proper controls is being considered.

PRC PROGRAMS—CONSERVATION AND DEVELOPMENT ENVIRONMENTAL CONTROL

In addition to its mine health and safety programs, PRC also has programs in the conservation and development areas. A representative example of recent advances in conservation and development is:

Water management. Acid mine drainage from abandoned mines currently pollutes more than 5,000 miles of streams in the United States. A new approach to the long-standing problem of acid mine drainage is the use of anionic surfactants to control an iron-oxidizing bacterium that plays a critical role in the rate of pyrite oxidation, and thus in the rate of acid mine drainage formation. In five full-scale field tests conducted by PRC, treatment of the bacterium thiobacillus ferrooxidans with a common biodegradable anionic surfactant (sodium lauryl sulfate) has reduced acid formation by 60 to 90 percent as you see in the graph before you. The surfactant is applied both as a solution and by gradual release from rubber pellets with extremely promising results.

PRC RESULTS

As with any high-technology research and development facility, the most valuable resource at PRC are its people. We currently employ approximately 250 full-time permanent employees, including 147 professionals and 89 technical employees. Of our professional employees, 24 hold Ph. D. degrees, 44 hold master degrees, and 73 hold bachelor degrees. A review of these statistics points out that approximately 50 percent of the PRC professional staff holds advanced degrees. All academic specialties relating to mining problems are represented; specifically, 19 technical specialties are currently represented on the staff.

As a measure of the scientific output realized by the PRC staff, it should be noted that in fiscal year 1981, our staff prepared a total of 77 manuscripts, 43 for outside publication and 34 for publication in the Bureau of Mines series. During the same period, our employees made a total of 68 formal technical presentations. An analysis of these statistics shows that for fiscal year 1981, one publication or formal technical presentation was made for each professional employee at the Pittsburgh Research Center.

In addition, from the period 1978 to the present, PRC employees have earned the Bureau of Mines five IR-100 awards. These awards are presented annually by the Industrial Research and Development magazine for the 100 most significant scientific developments in the United States. PRC projects recognized with this prestigious award are:

The reusable ventilation control stopping for underground mines;
The fibrous aersol monitor;
The trapped miner electromagnetic transmitter;
The self rescue breathing apparatus; and
Passive NO_x samplers.

In addition to the scientific output in support of Bureau research programs, our employees have been invited to represent the Bureau by a number of organizations. Sixteen of our employees currently serve on steering committees for various professional organizations. Other prestigious assignments include: U.S. representative to the UN group of experts on explosives.

These outside involvements, as well as the scientific contributions made by our employees, speak to the high level of technical expertise and the international recognition of the PRC staff.

PRC—PROGRAM FUNDING

The Pittsburgh Research Center receives funds to pursue both an in-house research program and a contract research program. For fiscal year 1982, the moneys received by PRC for the in-house research program total approximately $14 million; this includes $1 million which was received to fund research in support of other agencies' needs that closely coincide with the Bureau's mission, for example, the funding received from DOE for support of their activities.

FUTURE NEEDS

For PRC to maintain the quality of its research, it is desirable that the size and quality of its professional and technical staff be maintained. Integration of the Bureau's coal mine health and safety program and the coal productivity program currently carried out in the Department of Energy would greatly enhance the progress of both programs. As with the development of any production system, it is impossible to separate efforts to improve health and safety from considerations of productivity.

Thank you for the opportunity to appear before you.

Mr. WALGREN. Thank you, Mr. Murphy.

[The prepared statement, plus illustrations, of Mr. Murphy follows:]

STATEMENT OF JOHN N. MURPHY, RESEARCH DIRECTOR, PITTSBURGH RESEARCH CENTER, BUREAU OF MINES, DEPARTMENT OF THE INTERIOR

Mr. Chairman, I am pleased to appear before you today to present a brief overview of activities and accomplishments at the Pittsburgh Research Center, but first by way of introduction let me briefly outline the mission of the Bureau of Mines. I do this, primarily, to distinguigh the role of the Bureau of Mines from other agencies such as the Department of Energy, which are also involved with aspects of the minerals/energy problem.

The Bureau of Mines is located in the Department of the Interior. The major themes of the Bureau's mission have been defined by the Bureau's Director, Mr. Robert C. Horton, as follows:

1. Promote the wise and efficient use of mineral resources from initial extraction through ultimate disposal or recycling.
2. Promote the reponsible development of domestic non-fuel mineral resources with particular emphasis on increasing U.S. mineral supply invulnerability and reversing the decline in our Nation's mineral strength.
3. Maximize the development of sound health and safety practices in the minerals industries.
4. Contribute to an improved fundamental understanding of procedures and processes involved in the production and use of non-fuel minerals.
5. Develop and apply improved procedures and methodologies for the collection and analysis of mineral reserve, production and consumption data.

6. Contribute to the development and implementation of national mineral policies that meet the Nation's industrial, security, and human non-fuel mineral needs.

The Pittsburgh Research Center (PRC) conducts work in support of a number of the above themes. Moreover, it is the leading Bureau of Mines research center involved in the third theme, i.e., "health and safety practices in the minerals industry."

This theme, maximizing the implementation of sound health and safety practices in the minerals industries, is a proper concern at all levels of government not for only humanitarian reasons, but because poor health and safety wastes both human and financial resources, imposing an unnecessary burden on the economy, and affects our ability to compete with foreign sources of fuel. Health and safety problems can also adversely impact the development of domestic mineral resources. Past Bureau of Mines research has been effective in this area and it is appropriate that the Bureau continue research to promote and improve health and safety practices in mines and processing plants.

The Bureau's health and safety programs cover both fuel and non-fuel minerals. Past and presently planned emphasis is on coal mining, which is the most hazardous occupation in the United States today. It should be noted, however, that there is a great deal of potential crossover between the products of the fuel and non-fuel programs. Much of what is accomplished in coal has application to non-fuel minerals.

Of necessity, the Bureau's involvement in coal mine health and safety requires that the Bureau be cognizant of coal productivity concerns. It is the Bureau's objective to have its technological developments (aimed at improving health and safety) freely accepted by the industry. To insure this transfer, Bureau researchers must be mindful of the impacts of their work on mine productivity.

PRC PROGRAMS—HEALTH AND SAFETY

The Pittsburgh Research Center focuses on minerals health and safety problems encountered both in coal and in metal/nonmetal mining. PRC is the only Bureau of Mines facility that is involved in all aspects of the mining health and safety problem. The Center structure reflects this complete involvement and includes the following research groups:

1. Dust Control and Ventilation.
2. Methane Control (Systems Engineering).
3. Roof Support.
4. Industrial Safety and Training Systems.
5. Electrical Safety and Communication.
6. Explosives.
7. Fires and Explosions.
8. Environmental Control (Conservation and Development).

In order to convey to you the scope of activities of each of these groups, and to highlight some recent technical accomplishments, I have selected several projects from each group to discuss with you today:

DUST CONTROL AND VENTILATION

1. Dust control

Notable progress has been made in the control of respirable dust at working faces, but the problem has not been completely solved. Respirable dust problems specific to longwall mining are currently being addressed by an integrated Bureau program with the support and assistance of the mining industry and DOE. It is estimated that expenditures for this particular program will total $10 million over a 5-year period (1981-1986). One example of a PRC-developed longwall dust control technique is the "shearerclearer" which has demsonstrated its effectiveness in reducing the coal dust exposure of longwall shearer operators. The longwall shearer machine cuts coal using a drum located a few feet upwind of the operator and some of the cutting dust normally passes over the operators. The "shearer-clearer" is an airstream diversion system that moves the dust cloud away from and around the operator, thus reducing personal exposure. This dust cloud diversion is accomplished by simple realignment of the water sprays already installed on the shearer as a dust suppression aid. PRC research found that these existing sprays had air moving ability as well as dust suppression ability and that this air moving ability could be used to effect dust cloud diversion as well as dust cloud suppression, essentially tripling their effectiveness in reducing operator dust exposure. As a result of PRC research and development in this area, approximately ⅓ of operating longwall faces operating with double drum shearers currently use a version of the shearer-clearer system.

2. Ventilation aids

While ventilation is essential to underground mining operations, it is also one of the most expensive items to supply; this is due in part to the fact that only about 25 percent of fresh air which enters the mine reaches the working face and that typically mines must move several tons of air for every ton of coal extracted. To improve this situation, PRC has developed a variety of temporary stoppings (parachute, quick-fix blowout, etc.) that provide rapid, economical means of controlling ventilation airflows. As an example, in the case of the parachute stopping, western U.S. uranium mines report that a $600 stopping can save $5,000 a year in repair and construction costs. In the construction of permanent stoppings, as typically used in coal mines, recent studies have shown that a simple change from the trowling of mortar on a block stopping to a brush-on technique will double the breaking strength of the stopping and reduce the leakage by about 50 percent.

The ventilation of working faces to dilute potentially flammable methane is required in Federal and state mining regulations. In a room-and-pillar mine, typically a "line brattice" suspended on one side of the entry is used to direct the methane laden air from the working face. Regulations require that the "line brattice" be maintained withing 10 feet of the face, but experience has shown that under certain conditions, it is difficult to ventilate portions of the face. The Bureau has developed an ingenious but simple method to solve this problem. Named the "spray fan," it consists of locating and directing the water sprays on a continuous miner in such a way as to reinforce the action of the ventilation air in moving methane away from the working face. Over 350 continuous miners are now equipped with spray fans. This change which costs only a few thousand dollars per machine is so effective that MSHA has approved moving the line brattice back to 17 feet from the face.

METHANE CONTROL

If the methane from the coal seam can be captured before it enters the mine air, the mine ventilation requirements can be significantly reduced, and a valuable natural resource can be recovered and utilized. Hence, the objective of the PRC methane control program is to remove methane from the coal seam or adjacent strata either prior to mining or during extraction, and to pipe the collected methane out of the mine. Technical assistance is also being provided to DOE for their work in coal degasification.

1. Surface degasification of coal seams

Methane drainage several years in advance of mining through vertical or slant holes drilled into the coal bed is now a well-established procedure. This technique is now being, or is soon to be, used by some 10 operating companies. The American Public Gas Association is also using this technique for resource recovery for municipally owned gas companies. Current research in this area is directed primarily toward refining drilling techniques and improving methods for enhancing gas flows. At one drainage site in the Mary Lee Coalbed, reductions of from 38 to 62 percent in the coalbed gas content are estimated to have occurred in four years of drainage.

2. In-seam degasification of coal seams

PRC has also pioneered a technique of methane drainage through long horizontal holes drilled into the coalbed from the working face. The methane is piped to the surface through lines equipped with methane detectors that automatically shut off the flow in case of emergency. Several mining companies are now using this type of in-seam degasification. The current thrust of PRC research is toward longer horizontal holes.

Underground drainage is also being used to drain methane from gob areas. Slant holes, drilled from entries adjacent to a longwall panel into the overlying strata, carry the gas to an underground pipeline from where it is exhausted to the surface. At Bethlehem Mines Corporation No. 33 Mine, 55 to 60 percent of the total methane emitted during a longwall operation in the Upper Kittanning coalbed was successfully drained in this way. The mine is now using the same procedure at a longwall in the Lower Kittanning coalbed.

ROOF SUPPORT

1. Geology of roof, rib and floor

Accurate core logging is an important factor in determining the structure and composition of mine roof and overburden. Two pocket-sized guides to cored rocks in the Pocahontas Basin and the Pittsburgh Coalbed are now available to drillers, geologists and engineers; initial printings of 250 copies are already exhausted.

2. Temporary roof support systems

Setting of mechanical jack or wood posts under unsupported roof accounts for about 20 percent of all roof fall fatalities. Automatic temporary roof support (ATRS) systems can eliminate the need for mine personnel engaged in roof support to work under unsupported roof, and recently promulgated West Virginia mine legislation requires roof bolting mahines in working places to be equipped with such ATRS systems, regardless of coal seam height. An ATRS system has now been developed by PRC for single, fixed-head roof bolting machines used in low coal mines (less than 42 inches seam thickness). It consists of a ten foot long, steel, wide-flange beam supported by two double-acting, telescopic hydraulic cylinders; total weight is approximately 400 pounds. It is transported underground on the bolting machine drill head, using a speical stell sleeve attached to the bottom center of the beam. The ATRS was adapted to an FMC model 300 roof bolter for five months of underground evaluation in the production cycle of Imperial Colliery Company Mine No. 20, in Burnwell, West Virginia. The ATRS was preferred by the mine's bolting crews and MSHA to mechanical jacks for safety, ease of installation, and time saving. The ATRS is now part of the MSHA-approved Mine No. 20 roof control plan and is currently used in coal production. The prototype ATRS design can be retrofitted to any fixed-head roof bolting machine used in U.S. low coal mines.

INDUSTRIAL SAFETY AND TRAINING SYSTEMS

This group addresses two principal problem areas relative to industrial workplace health and safety, namely, hardware modifications and software such as training, human factors, engineering, etc.

1. Noise

Work is conducted to alleviate noise problems in underground and surface mining operations, and in coal and ore benefaction facilities. One example of this type of work has been bulldozer noise control. Approximately 50,000 mobile machine operators (or about 40 percent of all operators employed in U.S. surface mines) are overexposed to noise, according to current Federal machine noise regulations. Almost half of these noise overexposures are suffered by bulldozer operators. To alleviate this condition, PRC has developed retrofit noise control technology for the most commonly used bulldozers, the Caterpillar D9 and the International TD-25. This technology has been made available to the industry at 60 technology transfer workshops on bullbozer noise control which provided detailed instruction, including an instruction manual with all information needed to equip a bulldozer with noise controls. Over 800 people attended these workshops, and a follow-up survey conducted several months later showed that over 35 percent of the attendees actually applied the noise control treatments presented. Typically, a retrofit treatment costs about $1,000 and takes about 100 employee-hours.

2. Equipment

Roof falls are a major cause of mine fatalities. One preventive measure is to provide mine face equipment with cabs and canopies that protect the operator from roof falls and rib rolls. Since the inception of Bureau efforts to develop such protection, some 200 individuals have been saved from death or severe injury by PRC-developed cabs and canopies. A recently completed inventory of commercially produced cabs and canopies, sponsored by PRC, now allows mine operators to select protective structures designed for specific equipment. Based on this inventory, PRC is pursuing development of cabs and canopies still lacking for machines that present special design constraints, e.g. low coal machines. One such special problem has been resolved by a cab developed for a thin-seam (36-inch coal seam) bridge carrier which is now commercially available from Jeffery Manufacturing.

3. Materials handling

Manual handling of supplies accounts for some 24 percent of injuries in underground coal mines. PRC has now developed a mechanical handling system in which pallets operated by a forklift unload materials from supply cars and deposit them near their point of use. The forklift is a battery-operated, permissible, low-profile machine that can also be used for equipment maintenance. In a field test at Republic Steel's Clyde Mine, the mechanical handling system is expected to virtually eliminate injuries, with a 5 percent increase in productivity.

4. Illumination

Both safety and productivity in underground coal mines have been considerably improved by Federal efforts to provide better illumination. Over more than 10 years, PRC has developed numerous area and machine-mounted luminaries now used in operating mines. A recent significant addition has been the development of a low-glare luminaire for low coal mines, where testing of sample populations had shown the level of glare to be a severe problem. A small, low-glare, fluorescent luminaire is now available for mounting on low coal equipment. It operates on ac and dc current, and a snap-on diffuser effectively reduces glare. Approval for in-mine use will be requested from MSHA.

5. Life support

Following a mine disaster, the air may be oxygen-deficient and/or filled with toxic gas. To survive and escape under such circumstance, miners must be equipped with self-rescue breathing devices that supply oxygen without the need to inhale pollution mine air. Federal regulations require that every person going into an underground mine be equipped with a NIOSH/MSHA approved breathing device known as a self-contained self-rescuer (SCSR), capable of providing at least 60 minutes of self-produced oxygen. In the last 10 years, PRC has produced several SCSR's, the most recent of which is the SCEBA 60. It can be belt-worn, is relatively light (6.25 lb) and is a closed-loop apparatus with an external breathing bag containing compressed oxygen. The SCEBA 60 is undergoing certification trials by NIOSH.

A 2-hour self-contained breathing apparatus suitable for wear by mine rescue teams working in confined ares is also being developed.

6. Human factors

Many injuries in underground mines are attributed to footwear that provides inadequate traction on slippery surfaces. An alternative tread developed by PRC has been evaluated in underground mines where it has been well received by mine personnel and has decreased slipping and falling accidents significantly. The new boot should soon be commercially available from Iron Age.

7. Education and training

PRC has recently completed a research project to determine if organizational development methods could contribute to safety and productivity in underground mining. Organizational Development (OD) is defined as management intervention for the purpose of assisting an organization in solving problems considered important by the organization. More specifically, it is a planned effort to improve an organization's effectiveness through (a) team building and problem solving which concentrate on the issues of immediate concern to the organization, and (b) efforts to improve communication at all levels of the organization. At Texas Gulf and Hecla mining companies which participated in the research effort, each providing one underground experimental site, dramatic decreases in accident frequencies were recorded. At Hecla's Lucky Friday Mine, lost time injuries dropped from 21.4 to 4 per 200,000 man hour of exposure; at Texas Gulf lost-time accidents were reduced by 48 percent. Productivity increased 13 percent at Texas Gulf and improved slightly at Hecla. It would appear that OD not only can improve safety and productivity, but can provide an alternative to outside enforcement of safety regulations.

ELECTRICAL SAFETY AND COMMUNICATIONS

1. Electrical hazards

Accidental contact of mobile equipment with high-power lines is the single most frequent cause of electrocution at surface mines. MSHA had proposed regulations requiring installation of commercial proximity warning devices on crane and dragline booms, and on other equipment that might contact power lines. Extensive investigation by PRC established that available devices would not meet the intent of these regulations. As a result, MSHA has withdrawn a potentially costly and ineffective measure.

Novel mining systems being developed by DOE require large permissible load centers (2 MA at 15 kv). Current MSHA regulations on permissible equipment do not provide for certification of equipment of the needed size or voltage class. Research, funded jointly by DOE and BuMines, has developed a set of test standards which will allow MSHA to certify such equipment.

2. Routine and emergency communication and monitoring

Use of wireless systems greatly increases the range and flexibility of underground mine communications, and the capabilities of these systems are being continuously improved. Thus, use of a leaky feeder cable has considerably extended the range of UHF (ultra-high frequency) radio signals in various mines. MF (medium frequency) systems that can couple to and reradiate from existing mine wiring have made whole mine radio communications possible in underground areas equipped only with conventional mine wiring networks (telephone, power, etc). Preparations are being made to evaluate such whole mine systems for about one year at four mines: York Canyon, Magna Copper, Ranchers Exploration, and Plateau Mining. Other developments to be evaluated include a vest with built-in personal radio, and vehicular radios suitable for trolley-rail, battery-rail and rubber-tired vehicles.

If mine monitoring systems for gassy mines are to be useful and reliable under emergency conditions, especially during loss of ventilation, they must be powered by an intrinsically safe, uninterruptible power system; the sensors must also be intrinsically safe. A computerized monitoring system that meets these requirements, developed by PRC, is now commercially available and operating at R&P's Lucerne No. 8 Mine.

Much of the R&D accomplished for routine mine communications has found application in locating and communicating with personnel trapped underground following a mine disaster. In numerous mine tests, communication and location was achieved to depths of 800 feet using electromagnetic signals exchanged between miners underground and rescue teams operating at the surface. Current efforts are being directed toward the use of computerized receivers, and use of MF radios to establish communication between trapped miners and rescue teams that have reentered the mine.

3. Instrumentation

Both safety and health require instruments that provide reliable and accurate information on mine air quality, including respirable dust, gaseous contaminants and ventilation. Two personal dust exposure monitors are nearing completion. One uses light scattering to indicate dust levels near the wearer throughout the shift; it will calculate and display average shift exposure, storing averages for up to 7 shifts. The other uses a tapered element oscillating microbalance (TEOM) to measure the wearer's total end-of-shift exposure; the TEOM promises to replace the gravimetric system now used to ensure compliance with MSHA regulations.

Efforts of several years have developed personal, handheld and machine-mounted equipment for sampling and/or analyzing mine air for methane, carbon monoxide, and oxides of nitrogen.

One area of particular concern has been emissions from dieselized machines used underground. In laboratory trials with a filter made of stainless steel and fiberglass mesh, up to 90 percent particulate was removed from diesel exhaust, with or without water cooling. Under a Memorandum of Agreement with the Canadian Centre for Mineral and Energy Technology and the Ontario Ministry of Labour, this and other control treatments for particulates, oxides of nitrogen, carbon monoxide and unburned hydrocarbons will be evaluated.

FIRES AND EXPLOSIONS

1. Explosion quenching barriers

Recent mine disasters which involved explosions of coal dust have emphasized the need for additional protection against explosions propagating through mine roadways. PRC research has demonstrated that such protection can be provided by barriers consisting of troughs filled with various quenching agents released into the oncoming explosion. Currently, 50 troughs filled with water or solid quenching agents, and designed to be activated simply by the oncoming explosion (passive barriers), have been installed, singly or in groups in an operating mine complex. Over a six-month period of evaluation, their presence does not appear to have inconvenienced mine personnel. Full-scale explosion tests with other barrier types and arrangements are continuing at the Bruceton facility, and installations are planned at other working mines on a voluntary basis.

2. Frictional ignition suppression

From 1978 to 1979, the frequency of the frictional ignition of methane in underground coal mines doubled, with about 90 percent of the reported ignitions attributed to cutting bits on coal mining machines. Each such ignition has the potential for developing into a full-scale mine explosion. Extensive testing with a variety of new and used bits shows that frictional ignition can essentially be eliminated by spraying water into the cutting track directly behind the bit. A longwall shearer drum has been equipped with individual water sprays behind each bit, and is now undergoing evaluation in a mine in West Virginia. This technique represents a low-cost solution to the problem of frictional face ignition and may also serve to further reduce respirable dust.

3. Fire sensing and control

Early warning incipient mine fires in underground mines is extremely important for miner escape. A submicrometer particle (smoke) detector developed at PRC provides such warning, well ahead of other conventional detectors. It has also proved most effective in recent assistance that the Bureau has provided to mine operators and to MSHA in determining when sealed coal mine fire zones could safely be reventilated and reopened. Conventional techniques, based on the measurement of mine combustion products, are substantially less definitive for interpreting the state of sealed mine fires.

EXPLOSIVES

1. Permissible explosives

Evaluating the safety of explosives and blasting agents designed for use in potentially explosive mine atmospheres is the oldest continuing Bureau of Mines function. Based on a schedule of tests performed by PRC, these materials are approved and certified as permissible by MSHA; in fiscal year 1982, 11 new formulations were added to the official list of active permissible explosives. Through the years, this testing activity has both motivated and been supported by research and development that have made PRC an international authority on explosives and explosive phenomena. Currently, efforts are directed toward filling gaps in the approval schedules, which do not address such potential problems as desensitization of the explosives due to low temperatures, or to pressure produced by the firing of a charge in an adjacent borehole; such desensitization can result in misfiring or even worse, deflagration which is a potential source of ignition. Another current objective is the experimental development of permissible formulations that resist desensitization by exposure to low temperatures and applied pressure.

2. Non-incendiary sheathed charge

Occasions arise in mining where large rocks, such as loose hanging roof slabs, need to be dislodged or shattered but where access to the rocks in order to break them mechanically or drill boreholes for explosives is difficult or dangerous. In nongassy mines this problem can be solved with explosive charges, using a process commonly called mudcapping, but in coal mines mudcapping is prohibited because of the high probability of a mine gas ignition. PRC has recently developed an explosive charge with an integral sheath of ignition-inhibiting material, which can be fired safety in flammable atmospheres. This charge has been successfully tested both in the laboratory to verify that it does not ignite natural gas or coal dust gas atmospheres, and in the field, including an underground coal mine to evaluate its performance. Amendment of MSHA standards to permit its use under proper controls is being considered.

The preceding paragraphs are representative of recent advances in the area of health and safety technology achieved by the Bureau's Pittsburgh Research Center. The list is not intended to be exhaustive, but only to illustrate the nature of what is being, and can be accomplished to promote health and safety in mining. A more complete overview can be obtained from: United States, Bureau of Mines. Technical Highlights-Health and Safety Research, 1970–1980, March 1981, 181 pp (see Attachment).

PRC PROGRAMS—CONSERVATION AND DEVELOPMENT ENVIRONMENTAL CONTROL

In addition to its mine health and safety programs, PRC also has the programs in the conservation and development areas. These programs which are aimed at minimizing the adverse environmental effects of mining include: (1) Acid mine drainage control, (2) subsidence prediction and control, (3) mine and waste bank fire control, and (4) surface mine reclamation.

Representative examples of recent advances in conservation and development include:

1. Water management

Acid mine drainage from abandoned mines pollutes more than 5,000 miles of streams in the U.S. A current approach to the long standing problem of acid mine drainage is the use of anionic surfactants to control an iron-oxidizing bacterium that plays a critical role in the rate of pyrite oxidation and thus in the rate of acid mine drainage formation. In five full-scale field tests conducted by PRC, treatment of Thiobacillus ferrooxidans with a common biodegradable anionic surfactant (sodium lauryl sulfate) has reduced acid formation by 60 to 90 percent. The surfactant is applied both as a solution and by gradual release from rubber pellets with extremely promising results.

2. Solid waste management

More than 500 waste coal fires are currently burning on abandoned mine lands, polluting the atmosphere and threatening surface structures. Controlling these fires by conventional measures is difficult, costly, and very slow. PRC is exploring a new approach to the control of fires in abandoned coal mines and waste banks, based on controlled but rapid on-site combustion. An exhaust ventilation system draws the fresh air needed for accelerated combustion into the fire zone, and evacuates heat and combustion products to the surface. This heat, which can reach temperatures as high as 1,000°C, can be recovered to generate steam, hot water, process heat and electricity. Combustion products can be virtually eliminated by scrubbing as they travel upward. A field trial of the burn-out concept was recently completed at the Calamity Hollow Mine fire site in Western Pennsylvania.

PRC STAFF

As with any high technology research and development facility, the most valuable resource at PRC are its people. PRC currently employs approximately 250 full-time permanent employees, including 147 professional employees and 89 technical employees. Of PRC's professional employees, 24 hold PhD degrees, 44 hold Master degrees, and 73 hold Bachelor degrees. A review of these statistics points out that approximately 50 percent of PRC professional staff holds advanced degrees. All academic specialties relating to mining problems are represented at PRC; specifically, there are 19 technical specialists currently on the staff.

As a measure of the scientific output realized by PRC staff, it should be noted that in fiscal year 81, PRC staff prepared a total of 77 manuscripts, 43 for outside publication and 34 for publication in the Bureau of Mines series. During the same period, PRC employees made a total of 68 formal technical presentations. An analysis of these statistics shows that for fiscal year 81, one publication or formal technical presentation was made for each professional employee at the Pittsburgh Research Center.

In addition, from the period 1978 to the present, PRC employees have earned the Bureau of Mines five IR-100 awards. These awards are presented annually by Industrial Research and Development Magazine for the most significant 100 innovative scientific developments in the United States. PRC projects recognized with this prestigious award are:

The Reusable Ventilation Control Stopping for Underground Mines.
The Fibrous Aerosol Monitor.
The Trapped Miner Electromagnetic Transmitter.
The Self Rescue Breathing Apparatus.
Passive NO%Ox %1Samplers.

For the period of fiscal year 80 and 81 PRC, employees submitted a total of seven patents for work sponsored at the Research Center.

In addition to the scientific output in support of Bureau research programs, PRC employees have been invited to represent the Bureau by a number of organizations. Sixteen current PRC employees serve on steering committees for various professional organizations. Four PRC employees hold adjunct faculty positions at local universities. Two PRC employees are Federal Regional Disaster and National Emergency Bureau of Mines' Designees for the Federal Emergency Management Agency. Other prestigious assignments to PRC employees include:

The U.S. representative to the International Directors of Security Group.
U.S. representative to the United Nations Group of Experts on Explosives.
Technical adviser to the Environmental Protection Agency in the area of overburden analysis.

These outside involvements, as well as the scientific contributions made by PRC employees, speak to the high level of technical expertise and the international recognition of the PRC staff.

PRC-PROGRAM FUNDING

The Pittsburgh Research Center receives funds to pursue both an in-house research program and a contract research program. For fiscal year 1982, the monies received by PRC for the in-house research program total approximately $14 million. Of this, approximately $10½ million are earmarked for coal mine health and safety research, $1½ million for metal/nonmetal health and safety research, and $1 million for conservation and development research; approximately an additional $1 million was received to fund research in support of other agencies' needs that closely coincide with the Bureau's mission, for example, the funding received from DOE for support of their activities.

In the area of contract research for fiscal year 1982, PRC was authorized approximately $17 million. These are divided between coal mine health and safety funded at $11½ million, metal/nonmetal health and safety funded at $4½ million, and conservation and development research funded at approximately $1 million.

PRC-SPECIALIZED FACILITIES

The Pittsburgh Research Center manages three highly specialized underground test facilities that are unique in the world.

The Experimental Mine located on the Bruceton PA, test site is a twin entry mine fire test facility. The entry is 1,308 ft long and provides Bureau researchers with facilities to investigate the operation and performance of mine fire detection and suppression system.

The recently completed Lake Lynn Laboratory, located south of Uniontown, PA, is a multi-faceted facility configured to allow for use as a single entry development, a three entry development, and a full longwall face configuration. The facility consists of 7,538 ft of 7-ft high entry and 25,000 ft of 30-ft high entry. The initial activity at Lake Lynn will focus on explosion suppression systems.

The Safety Research Coal Mine located at Bruceton serves as a prototype operating coal mine, providing Bureau researchers with a general purpose facility for investigating a wide range of in-mine problems and new technology.

In addition to these underground facilities, PRC has a number of other unique research facilities and instruments. Selected examples include the new wire rope test facility, fire test galleries, a high-speed framing camera capable of 5 million frames per second, and "bomb proof" test chambers for the evaluation and testing of explosives.

FUTURE NEEDS

For PRC to maintain the quality of its research, it is desirable that the size and quality of its professional and technical staff be maintained. Integration of the Bureau's coal mine health and safety program and the coal productivity program currently carried out in the Department of Energy would greatly enhance the progress of both programs. As with the development of any production system, it is impossible to separate efforts to improve health and safety from considerations of productivity. This is the approach that the Administration has suggested in selected changes for the Department of Energy.

JOHN N. MURPHY

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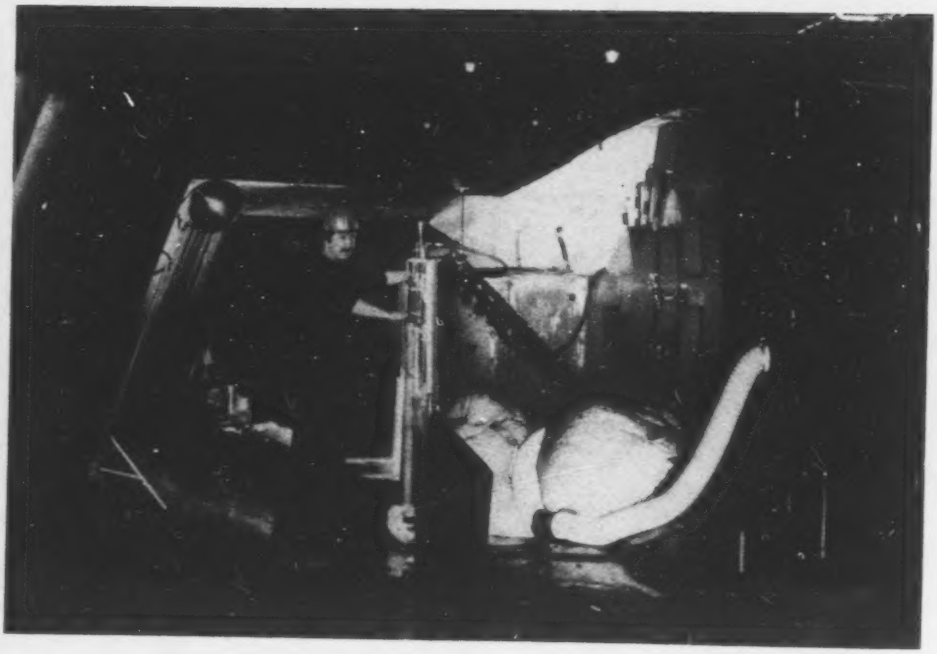
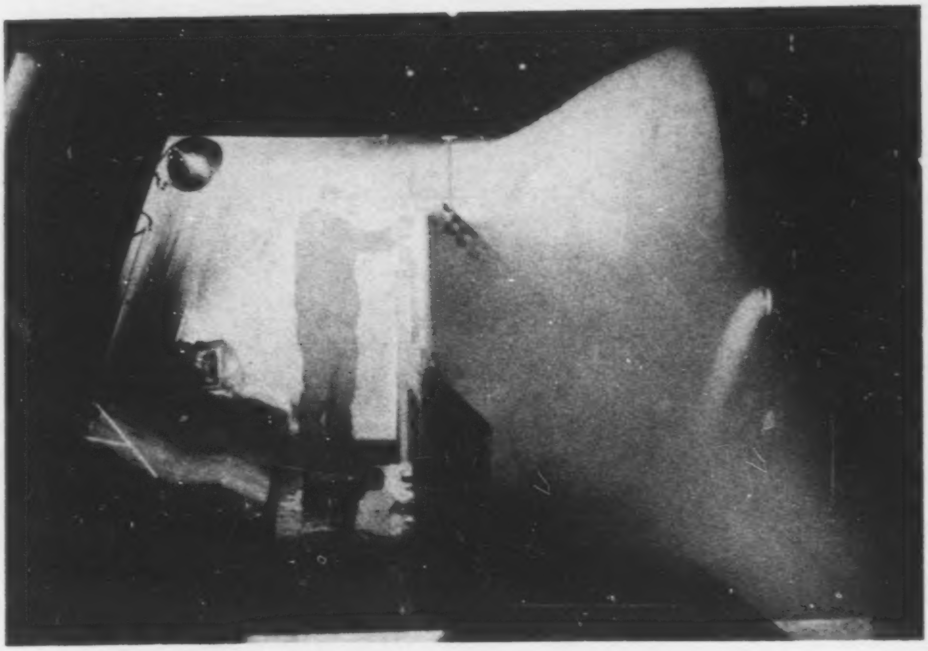
2. Job Description: As Research Director for the Pittsburgh Research Center, is responsible for the overall direction, control, and coordination of the research programs of the Center. The mission of the Center is research and development and to provide information and guidance to industry, other Federal agencies, and state and local governments on the safe handling and use of explosives and blasting agents, on fire and explosion hazards, dust control and ventilation, noise control, industrial hygiene, methane control, roof support, mine rescue and recovery, industrial type hazards and mine environmental problems such as acid mine drainage, subsidence, mine closure, reclamation and abandoned mine fire control.

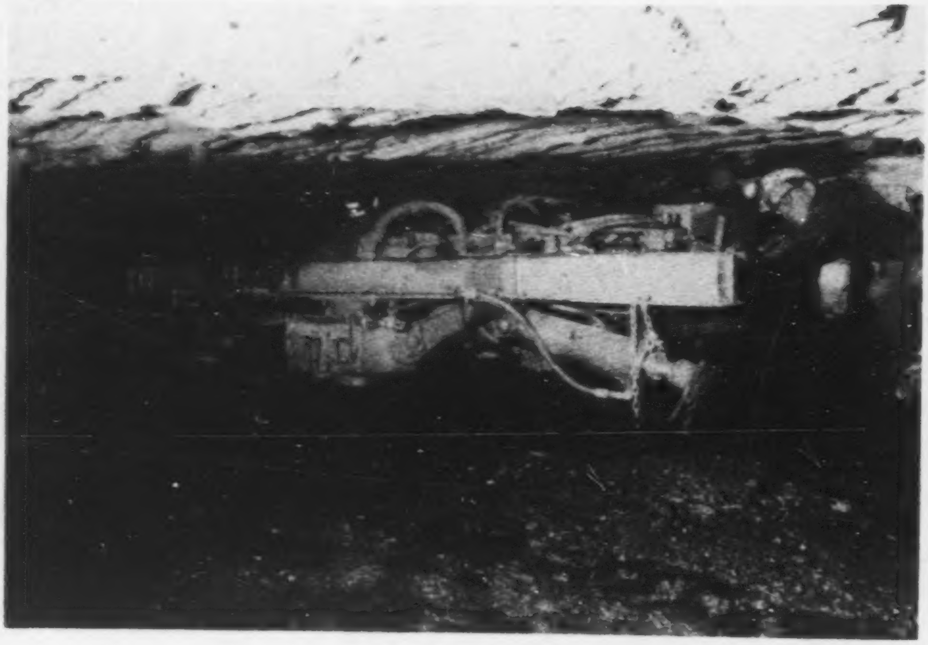
3. Place and date of Birth: Pittsburgh, Pennsylvania; July 14, 1939.

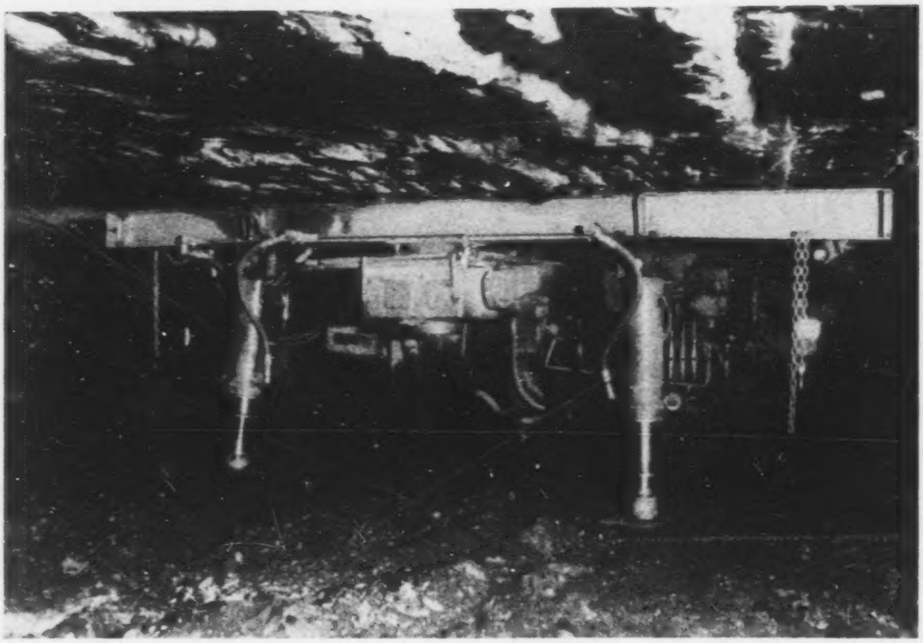
4. Education: University of Pittsburgh—B.S. 1961. Duquesne University—M.B.A. 1967.

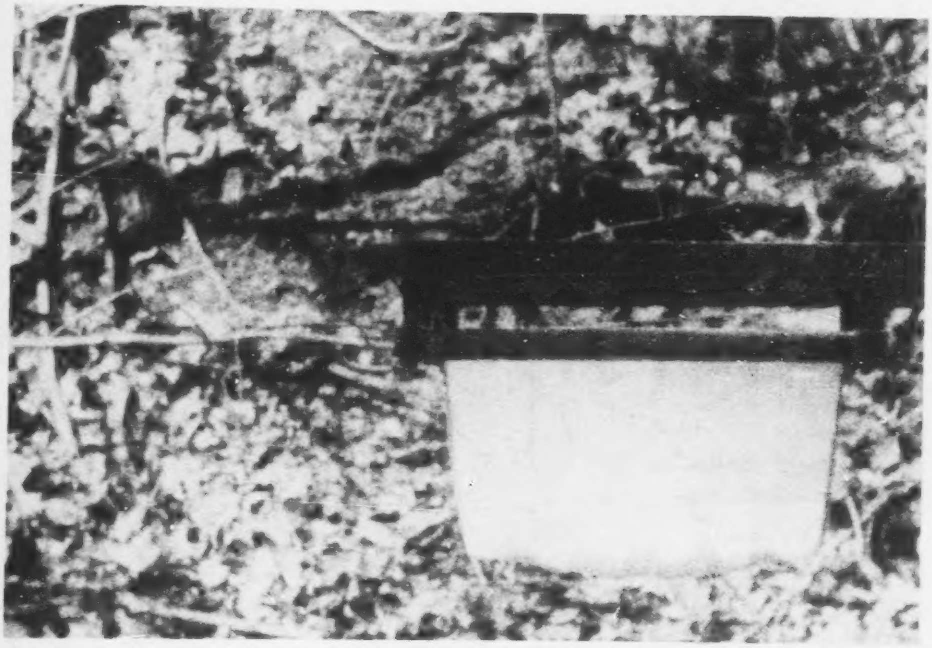
5. Work History: From 1961 to 1967 engaged in various technical and supervisory assignements with the Bureau of Mines. Served as Research Supervisor, Industrial Hazards and Communications, Pittsburgh Mining and Safety Research Center from 1967 to 1978. In present position since July 1978. Registered Professional Engineer (PA), Licensed Blaster (PA), Member of SME of AIME, Senior Member of IEEE.

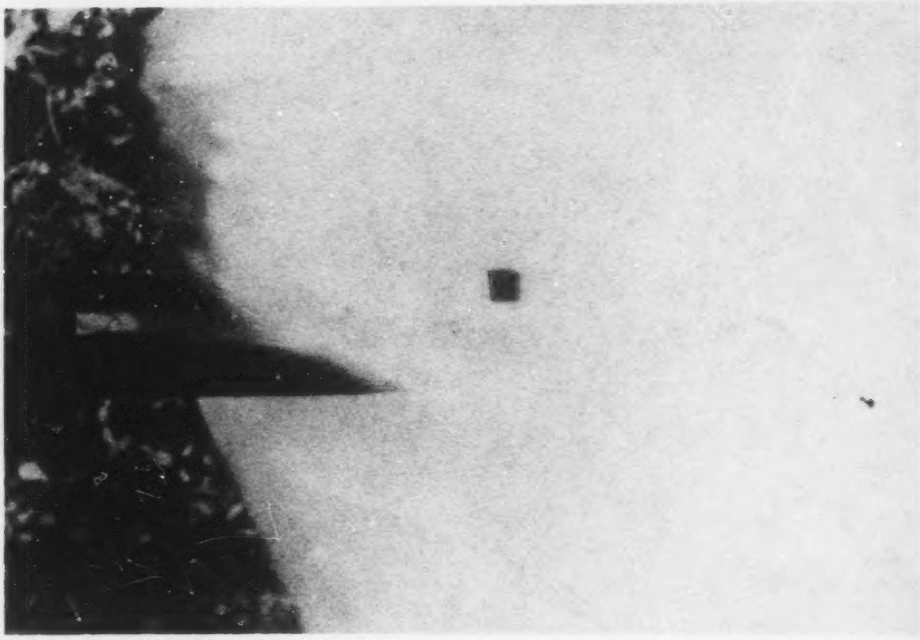


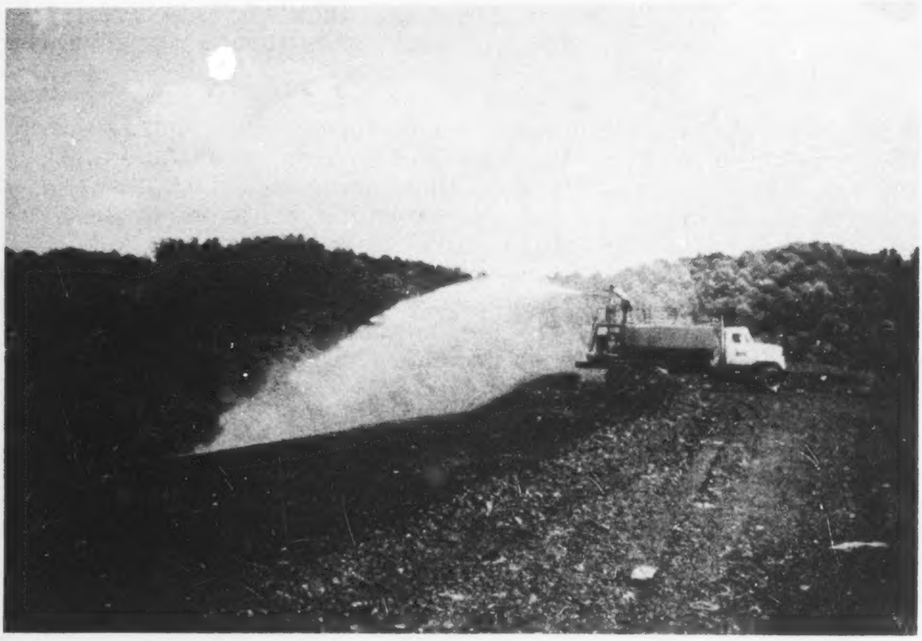












Mr. WALGREN. Dr. Hosler.

Dr. HOSLER. Mr. Chairman, Congressman Ertel, it is certainly a pleasure for me to come down today. I would like to run down the 300 projects we have under way.

Mr. WALGREN. Three hundred, did you say?

Dr. HOSLER. Three hundred-and-some projects, off-again-on-again projects. These projects all deal with the exploration for minerals, the extraction of minerals from the Earth, and the processing of those minerals for man's use, and certainly coal is one of the more important of those minerals, certainly to Pennsylvania.

I was just thinking as I was sitting here I think this is the 30th or 32d time that I have testified before congressional committees, starting in 1950, and the problem has not changed a bit. It is this off-again-on-again thing when it comes to research. We are terribly inefficient.

I recently visited the People's Republic of China and was asked to make some comments after I left, by the Government, about some of their work. They just underwent what they called the Cultural Revolution where for 10 years all of their research was interrupted, their education was interrupted, and it is a disaster that will be generations before they recover from in China.

We do this, also, about every 5 years, we have about a 5-year cycle of this off-again-on-again business in research.

I remember acid mine drainage. We spent millions of dollars of State and Federal money building a plant to learn how to treat acid mine drainage. After 3 or 4 years, it was shut down, and they built another plant somewhere else in West Virginia, as a matter of fact. On the topic of coal research, about 4 months before the Arab oil embargo, the Governor of Pennsylvania, the then Governor, shut down the Coal Research Board, and people in the legislature were saying, "We do not need coal research anymore, because we do not use coal. Coal is an old, outmoded fuel."

The new president of the university came to me, on the advice of people in industry, and said, "Shut down mining engineering. We do not need mining engineers anymore."

We suffer a great deal in this society not from the lack of a long-range plan, but as Max Williams was stating earlier, from a sustained effort in our research programs.

You argued or discussed a little earlier how do you decide which programs to have, and I think that the Congress together with the executive branch and people in the universities and in industry can debate about these things, and can make sensible recommendations on which direction things should go, but there is, as you indicated, this layering on top, this superimposition of political phenomena, where whether it is for true ideology or for partisan reasons or for economic reasons, such as the calamity we are in right now, suddenly the valve is turned off and turned on. Anyone who has learned to drive a car realizes you do not constantly punch the accelerator to the floor and then punch on the brakes. It is very inefficient. It burns a lot of fuel and it burns up a lot of rubber. We are doing the same things in our research programs.

I would give you another example at Penn State. We have a coal characterization program, and a sample bank into which the Federal Government has put millions of dollars. It is sort of like a library. We have thousands of samples of coal from all over North America, and thousands of people each year ask to have some of those samples or to have chemical analyses from those samples. It is a library of coal. Now we have been notified in February we are going to shut down the library. This is as if the Congress would suddenly decide to shut down the Library of Congress. This is a source of information, for everybody in the country who is engaged in coal research, and wants to try to liquefy some coal or gasify some coal and wants to know what the analysis would be, what kind of coal they should work with.

It is a very, very discouraging thing. As I say, we have 300-and-some projects in this small college that I am dean of. I might tell you a little about it, by the way. We have 2,500 students in the college, all engaged in these mineral fields. This is probably our most important product. If none of our research ever yields anything, we are producing hundreds of people each year who perhaps will be smarter than their professors and go to Gulf Oil or can go to Consolidation Coal or Continental Oil and will produce something of use or who will work here in the Energy Lab in Pittsburgh. This is our most important product. Their support depends on this research. Out of 500 graduate students we have, I think 400 are supported on Federal projects. We have several million dollars a year of coal or coal-related research out of a $12 million research budget.

This off-again-on-again thing not only interrupts the research and the permanent employees, it interrupts the students' studies. It constitutes a cultural revolution. We tell them we are not any more interested in supporting you in the type of thing you want to study. The country needs a sustained supply of these trained and educated people.

People think a long time ahead what they are going to study. If they see this uncertainty, they will not go into that field. They will go into something more certain, or they may even change in midstream, as occasionally happens now. So if I were to plead with you for one thing, it would be as Max Williams suggested, that the Federal Government start to introduce a program where we would put some sustained amount of money into research and development, whether it is a percent of GNP or tax revenues or what have you, and then we can debate about where it goes, but the fact that it fluctuates so wildly is a very inefficient process, and you are getting a very low production per dollar invested if you keep turning it off and turning it on.

In a field like coal research, if you are working on liquefaction or gasification, which involves everything from very basic research on catalysis to big engineering construction and flow diagrams for plants and so forth, in a field like that you have to build a team, and it takes years to build a team.

I am most familiar with weather modification research, which has had the same kind of experience. You take 5 or 6 years and you build up a team that is ready to really produce something, and then the funding goes somewhere else. That team dissolves. They all find vocations somewhere else. Then 5 years later you decide again you are going to go into this field. Someone has to build a new team. Political considerations shift the research around the

country, depending upon where the chairman of the Appropriations Committee happens to come from.

I have seen research where eastern universities had tremendous capabilities, and suddenly a program was shifted to the Bureau of Reclamation, and it had to be done in seven Western States, and the whole Northeast was cut out of the program, an extremely inefficient way to get production out of your research dollar. So I guess that my plea is rather than reiterate all the wonderful things Penn State is doing in coal research, to plead with you that you work within your committee to try to get some sustained level of research.

Certainly we went into energy research too fast. I was at MIT in the 1940's, and they had done most of the things in the 1930's which we have spent hundreds of millions of dollars to do over again in solar energy, if you judge from the reports coming across my desk. I do not know how many prototype south-facing windows we have built in this country, which the cavemen knew about. Literally we have done that. And so we started too fast. We went too rapidly to a very high level and could not efficiently spend it. Now we are going to precipitously drop this down to an artificially low level, which cannot sustain even the best programs in the country. So we have got to get some consistency into this, and that is my pitch.

Thank you.

[The prepared statement of Dr. Hosler follows:]

Testimony
of
Charles L. Hosler, Dean

College of Earth and Mineral Sciences
The Pennsylvania State University
University Park, PA 16802

before the

Subcommittee on Energy Development and Applications
Committee on Science and Technology
U.S. House of Representatives

The objectives of these coal research hearings have been stated to be:

1. To review the current status and recent achievements of coal science and technology.
2. To determine the size and quality of the scientific and engineering community engaged in coal research and development.
3. To determine the future opportunities and needs for coal-related R&D.
4. To assess the effectiveness of the federal R&D program in coal R&D.
5. To determine the federal role in coal R&D in a future with major constraints on the federal budget.

I have the following general observations to make with respect to each of the foregoing:

1. Coal research achievements during the past decade have equaled those of the previous half century but coal research is currently deteriorating at an alarming rate.
2. The size and quality of the scientific and engineering community engaged in coal research and development peaked in the 1980-81 period and now is experiencing a rapid decline.
3. The needs for coal research are self-evident once the status of our knowledge of this natural resource is understood and its inevitable role in the Nation's energy future appreciated.

4. The effectiveness of the federal R&D program in coal peaked prior to its "decentralization" in 1980 and has deteriorated since because of bureaucratic complexities and conflicts of interest.
5. The Federal government must assume a major role in funding future coal research; the states and the private sector cannot and will not undertake the required fundamental, applied and developmental research without significant federal support.

An enlightening survey was recently conducted on behalf of DOE by Penn State to determine the extent to which the Nation's coal resources were adequately characterized. The conclusions drawn from this survey were:

1. the Nation's coals were inadequately characterized for their efficient and effective use, this being particularly true in relation to coal conversion technology and maintaining environmental quality;
2. the number of agencies conducting coal characterization programs is too small to meet the Nation's needs within the time frame required;
3. the scope of coal characterization programs should be expanded to develop a broader spectrum of basic compositional and performance data.

The respondents in the survey included 58 governmental, industrial and academic agencies, all of whom were knowledgeable with regard to the Nation's coal resources and to information on coal characteristics. It was the opinion of of these respondents that 50-80% of the Nation's remaining coal reserves are inadequately characterized.

One of the achievements of the past decade that addresses the above deficiency has been the creation and operation of the Coal Sample Bank and Coal Data Base at The Pennsylvania State University. The Department of Energy (and ERDA and OCR) has expended more than two million dollars in creating this important research reservoir. Over the past four years, this facility has served the Nation's coal community by supplying more than 5000 samples and more than 4000 computerized data printouts to government laboratories, universities and industrial research organizations and the scientific literature is permeated with research results generated from these fully characterized coal samples. The Penn State Coal Sample Bank now contains more than 1300 coal samples derived from 25 states representing the 6 Coal Provinces in the conterminous United States. In response to changing needs Penn State is now developing the Premium Coal Sample Bank containing coal samples designed for researchers requiring samples permanently preserved in their *in situ* condition with all opportunity for deterioration excluded. Currently, six premium coals are available for distribution and a total of fifty will be available by the end of 1982.

Notable achievements also have been made during the past decade in basic coal research, in applied coal research and in process development. In the area of coal characterization these include:

1. development of automated microscope systems for the characterization of coal composition that have already found their place in industry in controlling the quality of coke oven feedstocks, and
2. development of procedures for characterizing the minerals in coal and determining their quantities; things heretofore impossible because of the inability to isolate the mineral phase from the organic phase without altering the minerals involved (this should open the door to understanding and controlling the horrendous problems and inefficiencies associated with slagging and fouling in electric generating plants).

In the area of coal gasification the achievements also have been numerous and include:

1. demonstration of fixed bed gasifiers operating in a mode that permits the use of caking coals,
2. elucidation of the gasification reactions and the catalytic effects of minerals and elements on these reactions including the development of a unifying equation describing all gasifying reactions,
3. demonstration of methods that cause a 30-fold increase in the reactivity of certain coals in the gasification process.

In the area of coal liquefaction similar advances have been attained in that:

1. increased understanding of the molecular structure of coal has permitted the accurate prediction of the chemical substances yielded upon liquefaction,
2. correlation of coal characteristics with liquefaction yields has resulted in the development of formulae that provide reasonable predictions of the quantities and qualities of the liquid products that will be derived from a given coal, and,
3. a microscopic method for monitoring the conversion process has been devised that promises to minimize problems in liquefaction and maximize liquid yields.

The Nature and Distribution of the Nation's Coals in Relation to the Distribution of University Coal Research Expertise

In contrast to the resources of many nations, the coals and peats of the United States are: 1) widely distributed, 2) of significantly different ages and 3) represent the full spectrum of the depositional environments and metamorphic histories through which such organic lithobodies develop. Their occurrence in climates ranging from arctic to semi-arid to sub-tropical has a significant influence on mining operations, as does their occurrence as unusually thick or thin seams or as steeply dipping or laterally variable rock bodies. Their distribution in relation to centers of population and centers of industrial development has strongly influenced the extent to which the coal seams have been exploited and this has been influenced further by the nature of the coals themselves. The result of all of this has been an extensive exploitation of Eastern, flat -lying, moderately thick, bituminous coals which have been formed in coastal plain or deltaic settings. This bias in coal usage has been reflected in the scope and effort characterizing coal research conducted during the first half of this century.

Coal is the most complex rock material to be encountered in the Earth's crust and coal seams are more complexly structured than other rock bodies. In spite of these facts, coal poses comparatively few problems in simple combustion and this has meant that a minimum understanding of its nature has been required to permit its utilization. More knowledge has been required in coal carbonization because this is, in effect, a refining process in which a product possessing certain characteristics is desired. Because combustion and carbonization have represented our principal uses of our coals, the research that was conducted (until recently) tended to focus on these areas *with the greater emphasis centered on carbonization, hence on coking coals. As research and graduate training are interwoven in university programs, it follows that the training of personnel has historically had the same bias.*

The end product of the factors described above has been the conduction of too little coal research, focused principally in Eastern bituminous coals, with insignificant effort expended in understanding the fundamental characteristics of coals in relation to all potential aspects of their utilization. *Moreover, the centers of research expertise and the coal-related educational programs, few though they be, have evolved in the Eastern Interior and Eastern Coal Provinces with minimal development in other areas of the Country.* When it is recognized that the bulk of the Nation's coal resources occur outside of these Provinces, and when it is realized that completely different coal types dominate in these regions, it becomes evident that an adjustment in our priorities is required. The University Coal Research Laboratory Program was aimed at making this adjustment. Although authorized by Congress, funds have not yet been appropriated to permit initiation of this important program whose mission is:

1. an increase in the total university coal research and training effort;
2. an increase in the scope of university coal research and training with adequate emphasis on understanding the basic characteristics of coal macerals and minerals, along with the properties of the Nation's numerous coal types and the significance of all of these materials in all potential aspects of utilization, and
3. the spawning and development of centers of coal expertise and training in all major Coal Provinces to insure development of the knowledge and trained personnel that future decades will find essential.

The Impact of New Technologies and New Concerns Over the Quality of Our Environment

In comparison to coal combustion and carbonization, the generation of synfuels from coal represents "high technology". The conversion of coal to high Btu gas, liquid fuels and solvent refined coal products will require the development and operation of "coal refineries" that will rival in size and complexity those employed in converting crude oil into usable products. The processing of compositionally complex mixtures of coal solids, liquids and gases in such systems will pose challenges which are not yet fully comprehended. Superimposed upon this is our desire to maintain and improve the quality of our environment. Our intent to insure against air pollution, water pollution and the defacing of the landscape will make an increased knowledge of coal characteristics and coal beneficiation mandatory. Still another challenge will be provided by the handling and processing of exceptionally large volumes of coal at a single site. In this connection, one is inclined to focus on the problem of waste disposal, but equally important will be the prospect of utilizing the waste material and deriving from it valuable by-products. In the latter connection, it should be noted that coals often contain useful metals in which are normally described as "trace" quantities. These trace amounts of such materials as copper, nickel, chromium, etc. may be upgraded to near ore levels in the "cost-free wastes" of synfuel systems.

It is evident therefore, that the advent of synfuel technologies and increased coal usage opens a new era of coal utilization, involving the application of sophisticated process systems to an exceedingly complex, and relatively unknown, raw material. To permit the orderly and efficient development of these new technologies, university coal research programs and related educational efforts must immediately adjust and respond to provide the knowledge and expertise so that they may be available when, and where, they are needed.

Universities and Coal Research

Solving our Nation's energy problems requires: 1) basic scientific and engineering advancements and 2) educated manpower. Universities are uniquely suited to fulfill these requirements.

The Case for Coal: Our Nation will depend on coal for economic and international trade stability for the remainder of this century. Coal is our most abundant national energy resource. We have 60 times more coal than oil and 40 times more coal than natural gas on an energy equivalent basis. Domestic coal production now provides for 20% of all energy consumed in the U.S. Projections show coal supplying 30-38% of our national energy needs by the year 2000. Transportation relies almost exclusively on liquid fuels. Synthetic liquids are the only alternative when world crude oil production cannot meet demands.

The Case for Universities: The phase-out of university coal research will result in three significant losses: 1) the loss of our ability to provide the trained manpower required to man our coal production and utilization industries; 2) the loss of coal research facilities, expertise and experience through their diversion and dispersion into other areas; and 3) the loss of important momentum toward acquiring the knowledge essential to the efficient and effective use of coal as a clean energy source. Should these cuts be approved, the government would be removed from essential areas of research which will not be assumed by private industry. These areas can broadly be classified as fundamental and applied coal science and there are several reasons why industry cannot pick up support of these areas. In the past and in the future industry will support the research relevant to its particular use of coal. Integrated research in fundamental and applied coal science will benefit all coal processing, mining, beneficiation, combustion, carbonization, gasification, liquefaction and the preservation of the quality of our environment. But, no single industry can justify the support of total coal science. It is clear that these losses counter efforts to insure the Nation with a stable energy supply. Much of industry's research efforts have been limited to problem solving rather than the development of new and improved technologies for the mining, beneficiation and utilization of coal. Universities are the only source for trained manpower, and, research is an integral part of manpower training at the higher educational levels involved. Moreover, only a few universities in the United States have developed the specialized skills and commitment to coal that are required for the long-term research that is essential to the productivity, safety and environmental issues that will be faced during the 1990's in the mining, processing and converting of coal to useful energy. Universities possess unique mechanisms for transferring advanced technological developments to private industries and national laboratories through graduates and adult education programs.

Recommendation: Logical justification to cut these university research programs does not exist. The Administration's philosophy of redirecting the Federal role to long-term, high-risk activities does not witness itself in these proposed cuts. It seems self-evident that coal research, indeed any research effort, cannot be productive with oscillations of funding in a feast and famine mode.

Dr. Charles L. Hosler
Dean, College of Earth and Mineral Sciences
The Pennsylvania State University

B.S., M.S., Ph.D., The Pennsylvania State University in Meteorology

Attended Penn State, Bucknell University, and M.I.T. Studied Metallurgy, Mechanical Engineering, Chemical Engineering, and Aerological Engineering

President, American Meteorological Society 1976 and elected Fellow

Elected to National Academy of Engineering 1978

Trustee and Treasurer of the University Corporation for Atmospheric Research, served on many federal panels and advisory committees and author of numerous scientific publications

Dr. Hosler has been dean of the College of Earth and Mineral Sciences for 16 years. The College offers B.S., M.S., Ph.D. degrees and enrolls 2400 students and conducts research in programs covering the exploration for, extraction of and processing of minerals and fuels. The College has more than 100 years of experience in all aspects of coal--formation, mining, processing and cleaning, chemistry and combustion of coal. More scientists and engineers working in coal have received their training at Penn State than at any other University.

Mr. WALGREN. Thank you very much, Dr. Hosler.

Dr. Baroch is not able to be with us now, but we will make his testimony part of the record at this point.

[The prepared statement of Dr. Baroch follows:]

STATEMENT OF
DR. CHARLES J. BAROCH
VICE PRESIDENT AND GENERAL MANAGER
ADVANCED ENERGY AND ENVIRONMENTAL SYSTEMS DIVISION

Mr. Chairman and distinguished members of the Sub-Committee, I am Charles Baroch, Vice President and General Manager for the Advanced Energy and Environmental Systems Division of Babcock and Wilcox. It is my pleasure to have the opportunity to discuss with you the current needs in coal research and development and to recommend the role government might undertake in these activities.

Babcock and Wilcox (B&W) has provided leadership in applications of steam generation since 1867. Our boilers powered Thomas Edison's lab, and most of our country's naval and merchant vessels. The Company is the leading supplier of coal-fired steam systems to electric utilities and industrial users of stea B&W has been known as a pioneer in fossil steam systems, and supplies complete systems including fuel preparation and air pollution control systems. We are proud of our ability to supply the utilities with partial or complete steam generation systems. Exhibit 1 lists a number of units in which B&W has supplied all equipment from the bunker to the stack, some units being operational within 48 months after construction began. Some current significant commercialization efforts being made by Babcock and Wilcox to promote the use of coal include the development of advanced pulverized coal-fired boilers, high solids coal-water slurries, wet and dry sulfur dioxide removal systems, atmospheric fluidized bed boilers, and coal gasification systems.

Identified needs to further improve coal utilization are the subject of this testimony.

Although coal has been a major source of energy for many years, additional R&D is still needed to improve the combustion efficiency, to reduce environmental effects and to convert coal to other forms of fuel. The areas for which R&D efforts are needed include mining, processing, combustion, gas clean-up and gasification/liquefaction. B&W is not involved in mining, therefore, my testimony will only discuss the latter four areas.

Coal Processing

The composition of coal varies significantly within and between deposits. Inorganic minerals that produce fly-ash and sulfur dioxide are the principal deleterious contaminants. These contaminants are currently removed from the fuel after combustion by the gaseous effluent treatment systems. If the contaminants could be removed prior to combustion, effluent and ash treatment systems could be simplified. Unfortunately, no economical process is currently available and research needs to be intensified to develop an acceptable process. Removing the contaminants will probably require fine grinding. If this is correct, then techniques for handling, storing and burning the very fine coal must be improved. The finely ground coal might be mixed with water to form a slurry that is handled like a liquid and can be burned directly in a furnace. This technology is in its infancy and data is needed on long term wear, combustion and pumping behavior of these slurries.

Combustion

Because of the wide variety of coals, additional work must be performed to better understand the combustion characteristics of the fuels. This data will allow one to improve the design of conventional furnaces, to reduce the amount of NO_x formed, and to design adequate gaseous effluent treatment systems.

The use of low-rank coals could significantly alter the design of the furnace and gas clean-up systems. Current research indicates that fluidized bed combustion may be most suitable for the low-rank fuels. Currently, TVA/B&W/EPRI are in the initial start-up activities with a 20 MW fluid bed system at the TVA Shawnee Station. This unit is a major pilot plant that should provide data for the design of a 100-200 MW unit. Additional efforts need to be made to better understand the capabilities of units like the 20 MW TVA unit and to demonstrate the capabilities and limitations of the pressurized fluid bed combustion systems, a second generation concept.

Combustion systems must be designed to handle lower grade fuels, coal-water slurries, and finely ground fuels. The combustion systems also need to be designed to reduce the SO_2 and NO_x formation. Some concepts have already been developed, but not adequately demonstrated.

Gas Clean-Up

A variety of systems have been designed to remove fly-ash, SO_2 and NO_x from the effluent gases. Although this is a very large business, the technology is still in developmental stages. Problems range from technical understanding of the processes involved to proper selection of components and materials of construction. These systems are expensive to build and operate. They also produce large volumes of waste products that must be handled and stored in an environmentally safe manner. R&D in all these areas needs to be expanded and accelerated.

Gasification/Liquefaction

Eventually coal gasification and liquefaction will be required in the U.S. to supplement oil and natural gas supplies. Today, obtaining combustion gases, gasoline and alcohol from coal is not economical. More developmental work is required to demonstrate the viability of the various processes, to confirm the design concepts, and to obtain more adequate data on the process economics.

Role of the Government

Private industry is conducting R&D in most of the areas described above. Some of the projects, however, are very expensive and industry has a tendency to avoid investing in projects with high costs, high risks, and potentially long payback periods. Therefore, in these areas governmental support is needed to insure the development of these technologies. I believe government support is required in the following areas:

1. Coal Gasification/Liquefaction - The cost of developing these technologies is very large and many of the large oil companies have even lost interest in this business. The Synthetic Fuel Corporation is a possible vehicle to implement this work, but their charter needs to be broadened to allow them to pursue projects for which the payoff and economics are less certain.

2. Coal Processing - A number of possible beneficiation processes are available to remove contaminants from coal. These processes need to be perfected and demonstrated on very large scale and with a large variety of coals. If adequate beneficiation processes are developed, it is possible that coal could be directly substituted for oil in both industrial and utility steam boilers. About 3.6 million barrels of oil are used each day in these boilers. The cost of developing beneficiation processes for a variety of coals may limit rapid development of this technology.

3. Fluid Bed Combustion - The small scale demonstration of this technology is being addressed by industry. The scale up to large utility units (> 100 MW) is beyond the means of most companies and utilities. The government work in this area for both pressurized and atmospheric systems should be expanded.

4. Coal-Water Fuels - Industry is, in general, conducting much of the research in preparing suitable coal-water fuels. The efforts to demonstrate the long term combustion effects, including wear of the components, and the ability to pump, store and handle the mixtures will require extensive efforts, most of which are beyond the current financial capabilities of industry. In addition, long distance pumping tests will be required to demonstrate the stability of the slurry and pumping requirements. This data is needed if the coal-water fuels are transported in slurry pipelines.

Biographical Sketch

C. J. Baroch is Vice President and General Manager of the Advanced Energy and Environmental Systems Division of Babcock and Wilcox, a unit of McDermott Incorporated. The Division provides gaseous environmental control, coal gasification, and fluidized bed combustion systems in the United States and throughout the world. In addition, the Division is responsible for the development of new and advanced non-nuclear energy systems and fuels such as coal-water mixtures.

Dr. Baroch was born in Colorado and raised in Nevada. He graduated from the Colorado School of Mines in 1954 with a degree in Metallurgy. He did his post graduate work at Iowa State University and received his M.S. and PhD degrees in Metallurgy-Chemical Engineering in 1956 and 1958 respectively. After serving two years in the U.S. Army, he worked for the Battelle Memorial Institute and General Electric before joining Babcock and Wilcox in 1965. With B&W, he has held a variety of engineering and managerial positions in the Research & Development, Nuclear Materials and Manufacturing and Advanced Energy and Environmental Systems Divisions.

He is a member of the American Nuclear Society, American Institute of Mining, Metallurgical and Petroleum Engineers, American Society for Testing and Materials, and Atomic Industrial Forum.

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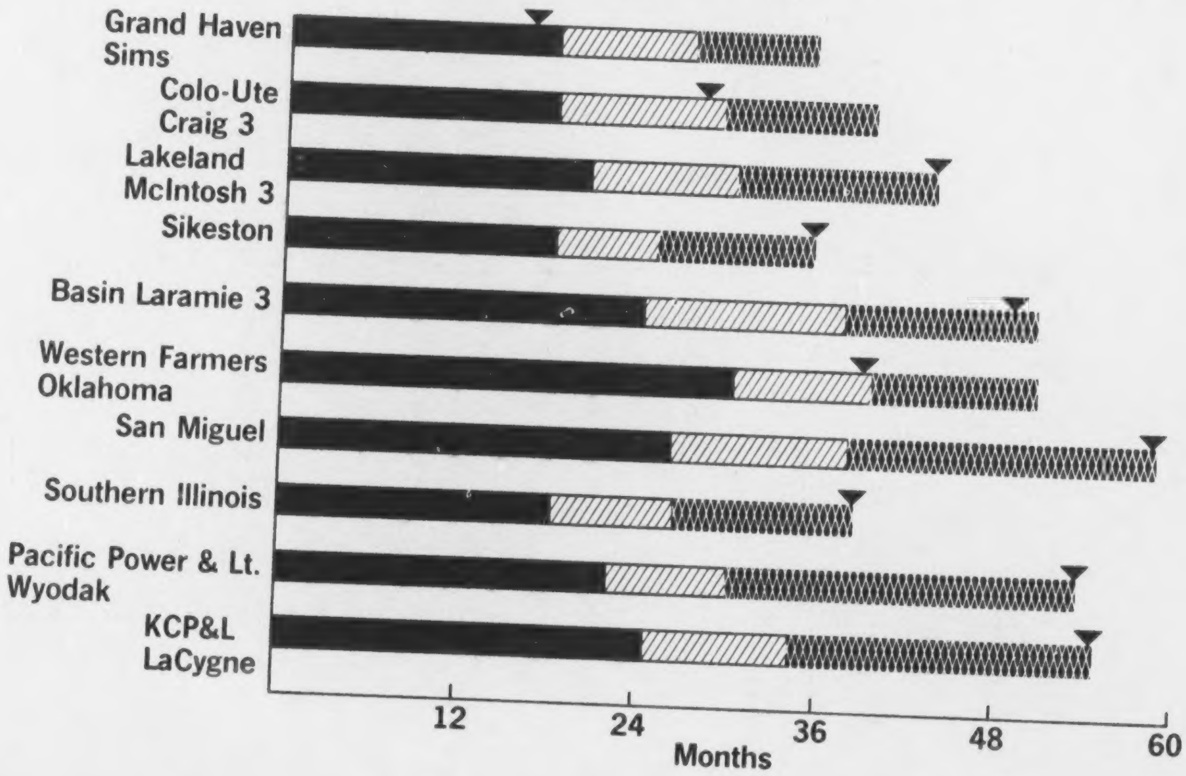

Mr. **Walgren**. Allen.

Mr. **Ertel**. Thank you very much, Mr. Walgren. I have got to say that the testimony is interesting, especially Dr. Hosler's south-facing windows. I do not know how many cavemen had windows, but that is all right.

Dr. Hosler, I am curious. You talked about having 2,500 students in your department of Earth and Mineral Sciences.

Dr. **Hosler**. Yes.

Mr. **Ertel**. How many of those will be affected by the cutbacks, the anticipated cutbacks in the national budget? How many do you expect to either be adversely affected or to lose from your department of earth and mineral sciences, do you have any idea?

Dr. **Hosler**. Half of the support has already disappeared from mining, and so I would say there that half the graduate students will be affected. The support will gradually be phased out for those graduate students. Overall in the college I would say of the 500 graduate students, funding for perhaps 200 of those under the proposed program will be eliminated. The undergraduates of course mostly come under their own steam, but again there is no doubt that if research in these areas is phased down, the stimulus for going into certain fields will decline.

We had a program for many years in fuel science, in combustion. Some years ago we did eliminate the undergraduate program in that area. We are about to institute it again, because we need to lead undergraduates into this area, to have them become graduate students, and to be the research people in combustion in industry and in Government and in universities, but we may have to rethink that again, because if the pull is not there on the top side for people to do the research, and for the graduate students, then we do not want to be pushing people into it at the bottom.

Mr. **Ertel**. I must admit that this is the first time I have ever heard the analysis between what is happening in our educational systems and our cultural systems and our learning systems if you will in the United States compared to the cultural revolution in China. I am not sure that it is not a bad analogy. I think I can see some analogies that we are turning away from the pursuit of knowledge, pursuit of learning, pursuit of expertise and knowledge in scientific areas by our cutbacks. We seem to me to be somewhat shortsighted.

As you have indicated, in China they went through the cultural revolution and that they are taking a long time to come out of that process. It seems to me that your analysis is excellent, because what we are doing is cutting our investment in human resources, and that is hard to replace. It is hard to replace the ability of a trained mind in our society, and I see that coming very dramatically.

When I heard the testimony previously from some of the people in the cutbacks of some of the programs that we will not have these trained personnel, losing one-third of the people at this energy center is going to discourage any person from pursuing a technical field, because he is not going to see a career or an opportunity, and I think the analogy is frightening but accurate, and it gives me a great deal of concern.

I wondered if either Mr. Murphy or Mr. Merten would like to comment on either Dr. Hosler's comments or my comments based on what he said, because I think they are right on point.

Mr. MERTEN. I am not sure I would want to push the analogy to the cultural revolution in the People's Republic of China very far, but as I indicated——

Mr. ERTEL. Maybe the degree might be a shade off and there probably will not be rioting in the streets, and there will not be that kind of thing, but the failure to develop the mind may be the same.

Mr. MERTEN. Yes. I do agree to that extent. As I indicated earlier, we do feel that the highest priority for the Federal Government in coal research is to make sure that there is adequate money funneled into teaching environments, and I think the teaching part of it is very important. The fact that work is done in a university is not necessarily evidence that it is being done in the teaching environment. We are talking about the research which is done by the academics who are active in teaching, who have graduate students, who interact with undergraduates and so on, as opposed to being perhaps in an institute associated with a university, but not taking part in the education process.

Mr. ERTEL. Do you have any comment, Mr. Murphy?

Mr. MURPHY. Yes, just to add to that. Having a core expertise to implement and manage any program is important, and while you certainly can tolerate some fluctuations in size of programing, you have to have a critical mass in any given area to effectively manage that particular area. This needs to be kept in mind.

Relative to training of new and up-and-coming scientists, I think the the Pittsburgh area is a very good example of where that works well. To use ourselves as an example, we have many instances of students who work at our center on a part-time basis while continuing their studies, and then return to the Federal community. In some cases they go to private industry, but the center has still been a good training ground in terms of their future pursuits and contributions to the public.

Mr. ERTEL. Are you being cut back at all, Mr. Murphy, in the 1982–83 budget? I notice your testimony went through the existing budget, but it did not anticipate the following budget. What, if any, impacts will the submission of the President's budget have upon your particular institution here?

Mr. MURPHY. The Bureau's health and safety program, which is the principal source of funds for the Pittsburgh Research Center, is I believe proposed to be cut from $54 million to $45 million in 1983, and the work in the conservation and development area is proposed to be cut from $12 million to $7 million.

Mr. ERTEL. What will the impact be on your particular groups here, if you can translate that?

Mr. MURPHY. Well, it certainly reduces the funding that we have available. It will have some impacts on personnel. The personnel ceiling is separate from funding, in that up to this point our reductions have been in the contract program. We do not expect any significant reductions in force except by attrition. However, we have not been able to replace people who have left. Nevertheless, we expect to maintain a core expertise in essential areas, making slight realinements as the need for changes in program emphasis occurs.

Mr. **Ertel**. Dr. Hosler.

Dr. **Hosler**. I just would like to say something about the comment that Mr. Murphy just made, that they would cut down in contracts and not in personnel in the Bureau of Mines labs. While I feel for the employees of the Bureau of Mines labs, I feel that as these cuts take place, if indeed they take place, one must consider the seed corn back at the universities, and that contracts be maintained at a level where they can involve graduate students, and where they can maintain their equipment and their plant.

I think maybe the cultural revolution analogy is or is not a good analogy, but I think there is an analogy in this business that does apply, and that much of the trouble that American industry, particularly our heavy industry, is in right now is due to the failure to make the investments over the years that have passed to bring their plants up to date, and to bring their productivity to a high level, and we can have that same failure in our educational institutions. They require capital investment, too, to maintain their physical plant and their equipment, and the minds that are there, and knowledge is a form of capital certainly that does accrue interest. You can either spend that capital or you can invest it, and I do not think there is any better place to invest it than in universities, where it indeed does earn interest in terms of turning out new students, new engineers, and new scientists, so I would hope that the Federal Government as it cuts back would look at this and make those cuts in an equitable manner, to assure that the universities maintain their viability as research universities.

Mr. **Ertel**. Yes?

Mr. **Murphy**. Could I elaborate on that point for just a moment, please?

I share Dr. Hosler's concern, but let me use an example that relates to our involvement with Penn State University and some of the other local universities. It relates to our electrical power distribution program, which has been substantially implemented through Penn State, West Virginia University, University of Pittsburgh, and some industrial concerns in the Pittsburgh area and in other parts of the country.

We have an in-house expertise that consists of approximately three professionals responsible for electrical power distribution, and who have effectively managed the integration of the various parts of the program at the organizations I have mentioned. It is clear that I have little flexibility in terms of reducing a three-man professional core of expertise when my funding is reduced. If we are going to maintain the level of expertise needed to manage electrical power distribution work effectively, and I have little flexibility to reduce that, it unfortunately becomes the contract program that has to be reduced. This is just one of many examples that relate to that same small core in-house expertise, and working under contract with the academic and industrial community.

Mr. **Ertel**. Let me just change the subject for a moment. We had a rather spirited discussion with the last panel over what should be the Federal Government's role in research and development, and one of the things I have heard at least from Dr. Hosler and I think

I heard from all of those was stability, stability in funding so that people can anticipate and really make a program that made some sense. I think Dr. Williams sort of indicated that, too, that we ought to have some strategic planning and then follow through with it.

What should be the role of the Federal Government in the research and development effort? Where should it stop with its research? Should it stop at the very low level before you even do a pilot project, or should you go further through the pilot project and then let the commercialization take over? The problem I saw in the discussion we had before where we related only to high capital intensive projects. Second, where would the money come from for those high-capital-intense projects?

Now Gulf might come up with some of that money, but I would suggest that for a lot of those which are in the billion-dollar range, they are not going to come up with much. They cannot afford to, and I do not know how much other industry can do.

Second, how do you relate the national interests into that beyond the economic interests of just having a productive economy here? Do we have a national interest beyond just economics?

I would be glad to hear from any of you on that.

Mr. **Merten**. Well, we do believe that the Federal Government has a role to play all the way through the demonstration plant stage in the case of technologies in which, as you indicate, there may be a national interest which goes beyond a commercial interest, and this is true of some of the major energy technologies. Private industry would certainly develop these independently, but at a pace which is determined by normal commercial considerations, and not necessarily by national security interests, for instance, or balance of payments problems.

I think the earlier panel really got down to the nub of that when they dealt with the way these programs have been managed in the past. We are also, as Dr. Sudbury indicated, disillusioned with the previous demonstration plant program, which was somehow not properly structured, and hope that a better way of structuring these programs, selecting projects and so on, can be developed.

Mr. **Ertel**. So you are saying basically we ought to be in that program, but it ought to be better managed.

Mr. **Merten**. It has got to be done right, and the various parties involved have to play their proper roles.

Dr. **Hosler**. Congressman Ertel, I think you got to the point in the other panel also talking about strategic importance of certain industries and productive capacities, and I personally tend to view a coal liquefaction plant or gasification plant or methanol plant in the same category I view the missiles. You may hope you never have to use it, you can buy cheap oil from the Arabs or from Venezuela, but by gosh you had better have it in case it becomes necessary, so I think when you do it through the Government building and operating these things, I doubt it.

I think traditionally you have used tax incentives and other devices to make it profitable. I guess in 1917 we decided to subsidize sugar beets, because we were worried we were not going to be able to get cane sugar. Now I think 65 years is a little long to go on that program, and we probably could drop that, but certainly the analogy I think could be used up to a point there, that if it is a little costly to produce the liquid product right now, then the Government has got to subsidize it. Whether you do it through tax incentives or direct subsidies, that is up to the wise minds in the Congress, it seems to me, but we do, it seems to me, strategically need to be able to have something, have an ace in the hole, when it comes to dealing with the Arabs and oil.

Mr. **Ertel**. I appreciate your point of view, and I think something that we have always missed when we have a lot of these discussions, we talk about these very large plants, demonstration plants and so on, but we also forget the fact of leadtime. Leadtime for these plants is 8 or 10 years to get them to the productive stage. If we have an oil embargo tomorrow, 8 to 10 years is not going to help many of us in this Nation, but the other thing I appreciated Dr. Hosler, was when you said that in the final analysis we are subsidizing, whether it is tax incentives or a direct subsidy, it is direct money. If you think that you have a certain taxing level, and then you make exceptions for a particular thing, we tend to call it tax expenditure. It is the same thing as a subsidy. We are giving them a special break, whether we take the money from somebody and give it to somebody, or we just do not take the money, which would normally be taken. I do not see a great deal of difference in how you are treating that.

So when everybody comes in and says if you just give us a tax reduction or you give us a tax credit, we do not want to be subsidized, I sometimes wince a little bit when I hear those terms, because it really comes down to the same thing in many respects, so I guess it makes people feel a little better to say that way, but I am not sure it makes much practical difference.

Dr. **Hosler**. There is one fine difference. If you give direct subsidy, the chances are it is very carefully directed in a specific way, whereas if you do it through taxes, they may have a little more flexibility, where they can direct their efforts in terms of their assessment of the economy or the feasibility of some type of process, and I think sometimes where the Government goes wrong is things get too highly directed, and you lose the flexibility to move where a technological breakthrough may enable you to go or where the economy may dictate you should go.

Mr. **Ertel**. I guess there is just one corollary to that. You also find that with tax expenditure, if you call it that, or tax credit, there are some very clever lawyers in this country. They seem to be able to make that into what is called a tax shelter, which shelters income and probably is not very productive. We have seen that with some of the recent revelations of certain leading officials in the administration who have bought into a tax shelter which they never really expected to buy out of. It is just to save them tax money. It was a waste of money, if you will, so you have to be careful about that, too. I appreciate the flexibility end of it.

Thank you, Congressman Walgren. I think I have exhausted my time.

Mr. **Walgren**. I appreciate the areas that you have covered, and it may be about what we do want to cover here.

I want to just ask Mr. Merten, in your testimony you indicate the possibilities of organizations leading government research who would have a direct interest in the commercialization of the process. How do you deal with the problems of proprietary information under those circumstances? Is there a way that we could engage in large research projects that would allow the information to be shared properly?

Mr. **Merten**. Yes, I think there are ways to do that, Congressman. One of the things in which our Government's attitude seems to differ from that of many foreign governments is in sort of a paranoia about someone making money off of the fruits of this research. It seems to me that the terms under which proprietary ownership will pass to a company should be a negotiable part of the contract under which that company agrees to do the research, and if one of the rewards for the company is an ownership of certain rights or a further involvement in that technology in the future, that should be regarded as a positive rather than a negative.

Mr. **Walgren**. I ought to say this is Allen's area, if you may want to comment on it.

Mr. **Ertel**. Thank you. I spent approximately 3½ years trying to develop a patent bill, the transfer of patent rights as a result of the Government's research and development. We have part of that in effect in the universities as you are aware and small business. There is one patent area left to be taken care of. That is what is not typically a small business which would affect your company.

You have a very difficult political argument, because what they are saying is that we are giving away an asset of the United States Government by the transfer either of technology, through the research and development efforts of the United States Government, or if we actually transfer that to a corporation, through a patent which gives them exclusive right. It is not a heck of a lot of difference if you have got the ability to package that knowledge and use it yourself. I feel like you do, that if the United States economy improves by it, we are much better off if it is used rather than winding up on the shelf, which we have traditionally done in this country.

Mr. **Merten**. Right.

Mr. **Ertel**. And so we come up with a compromise patent bill which we should be moving which will probably be of benefit and of interest to you.

Mr. **Merten**. Good.

Mr. **Ertel**. Thank you, Congressman.

Mr. **Walgren**. Mr. Murphy, I wanted to go back just to the budget cuts, and understand exactly what is going on there. You had $14 million in 1982 in the Bureau of Mines research efforts; is that right?

Mr. **Murphy**. For 1982 at the Pittsburgh Research Center we had $14 million for in-house efforts.

Mr. **Walgren**. And what is your projection for 1983 under the President's proposals?

Mr. **Murphy**. The answer that I had previously provided was at the headquarters level; the entire Bureau health and safety program funding for 1982 is presently on the order of $54 million. It is my understanding that it is proposed to be reduced to approximately $45 million; in the case of the conservation and development program, reduction would be from approximately $12 million to $7 million.

Mr. **Walgren**. And why have we not merged health and safety with production? You mentioned that they will be merged. Now why has that not been done in the past if that would be helpful?

Mr. **Murphy**. Because the coal productivity work at the moment organizationally resides under the Department of Energy's jurisdiction. At one time it was within the Bureau. When the Department of Energy was formed, this work was moved to DOE. It has been proposed by the administration for return to the Bureau.

Mr. **Walgren**. I see. I had wanted to ask what your efforts are in the Stevenson-Wydler area, and how you identify within an operation such as yours the efforts in transfers of technology. The Congress has tried to encourage the research laboratories in particular as you know, to do everything they can in that area, even involving set-aside or at least the knowledge that a certain effort is made particularly in that area. As you know, I was interested in the mine fire technology which would draw some heat out of some mine fires and manage them at the same time. Can you tell me a little bit about our efforts in transfer technology here, and where you see the Bureau being able to go in that particular instance?

Mr. **Murphy**. Yes. First of all, in general the Bureau has been rather active in technology transfer, but in this particular instance, pertaining to the controlled burnout experiment that you have referred to, it is in the conservation and development area where, as I indicated, the funding is proposed to be cut in half. I was extremely pleased to learn that I may get enough funding from our headquarters office to finish the field project that we had the pleasure having you visit. However, with the limited funds, our headquarters office has not been able to provide additional funding to pursue controlled burnout to a demonstration phase. We have completed the concept proof in the field. It appears to be quite feasible, but our efforts next fiscal year will be limited, per the current plans, to completing and documenting the field work, so that it will be available for others to pick up and pursue. Further questions remain relative to the application of this technology to coal refuse piles.

Mr. **Walgren**. Are there ways that you could cooperate with in this instance the county, that would not be an additional cost to you? I am hoping that something like that might develop, because the county, of course, in this instance is as limited in their financial abilities as you are.

Mr. **Murphy**. Yes. What we had originally proposed to the county was to provide onsite technical assistance in terms of a field investigation to determine the applicability of the controlled burnout process to the site under discussion. At this point we can, without any additional funding, provide some technical guidance.

There is a question that remains. The real hiatus in terms of the transfer of this technology is that it resides in some experts we have. We ultimately wanted to get it in the public sector in terms of A&E firms and so forth. This involves an educational process. We can provide some technical assistance, but I think it is probably going to extend the transfer time.

Mr. **Walgren**. I want to encourage you to consider that project and whatever can be done for it, and I will certainly be talking with your office and the people in the county to try to encourage that to happen.

Mr. **Murphy**. We certainly appreciate your interest in the project. We think that it is very interesting, with applications in many areas.

Mr. **Walgren**. Dr. Hosler, the coal data bank at Penn State, how is that financed and backed again?

Dr. **Hosler**. That is financed by the Department of Energy. The first contract was in 1975, I believe, and that has been going on and it is now slated to expire in February. There is still 60 or 70 percent of the coals in the country that have not been characterized, that are not in the bank. It seems to us that the first thing you do when looking at an energy source like that is to take an inventory to see what you have, what its quality is, and what the properties are, and what it is useful for, and it is clearly something that we feel is of a benchmark character that is basic to much of the coal research going on, and right now it is scheduled to be phased out.

Mr. **Walgren**. What happens when you phase it out?

Dr. **Hosler**. We built a building for it including university money and Federal money.

Mr. **Ertel**. He is pointing to us like we are the Federal money.

Mr. **Walgren**. Dr. Chun.

Dr. **Chun**. That program was supported by PETC, and over the last few days we had some conversations with Senator Heinz and the Penn State management as well as the Assistant Secretary for Fossil Energy. That program is running at a rate of approximately half a million dollars a year, and we are very supportive of that program, we will continue to be very supportive of that program, and I think that message has been conveyed to all parties concerned.

The problem that we face is the same problem that I discussed earlier. If the fossil energy budget is cut from $400 to $100 million, and if the coal bank, with all its merits and the support to academia as well as other functions, half a million is a rather large cut of $100 million total fossil program. So based on a $107 million fossil energy program, there will be a reduction in programs all over the map, and it so happens that this program was one of the 75-percent cuts that we will have to make, so that is the situation that we are facing.

As I mentioned earlier, programmatically both our staff and the headquarters staff, believe that it is a worthwhile effort to push, and we promised Senator Heinz' office that we are very supportive of that function, but financially you know where we stand. It is self-explanatory.

Mr. **Ertel**. Let us assume for a moment you go forward to cut the program out, not because you want to, I understand that, but just because of the national administration you do. What happens to the library that has been accumulated? What happens to the future classification? What happens to all those things? What happens to the building?

Dr. CHUN. I cannot speak for that particular program at this point in time, because we still have the contracts effective until February, but as an example, we just closed a station in Carbondale, Ill., this month. Carbondale Mining Technology Center was a mining technology center for DOE, and PETC used to manage that function, but due to the reduction in mining program as well as a streamlining effort, we shut Carbondale Mining Technology Center, so most of the library's materials and information has been sent to us, so we are now in the ownership of all the technically based information.

Now what will happen, the Penn State situation is somewhat different. What will happen to those materials as well as the information base? We will have to come up with a plan as to how to deal with that. The situation is somewhat different, and it is rather typical of the situation where the contract has to be terminated, whether it is SRC-II or coal bank, when the contracts are terminated, certain information base will be transferred to PETC, and it will still be made available to the public.

Some other things, the hardware, the materials and what not, usually they are terminated, put into mothball status, or dismantled.

Mr. WALGREN. Do we know about the building in this instance?

Dr. HOSLER. Dr. Spackman, who directs our coal research section, is in the audience if you would care to have him comment. I think he has visitors from Holland today, where they are trying to set up a similar coal bank, if you would like to have Dr. Spackman comment.

Mr. WALGREN. We certainly would.

Dr. SPACKMAN. I am William Spackman, director, Coal Research Center at Penn State University. I think perhaps I can amplify a little bit on what has been said. We initiated the development of the sample bank and data base back in 1968 under the auspices of OCR. A sizable amount of the funding for the development of this sample bank and data base has indeed come from the Federal Government. I have attempted, however, to expand the source of funding in order to provide for the needs that were not met totally by Federal funding. The non-Federal funding still is only a small portion of what is involved.

I think it is important to recognize that this sample bank and data base has come to serve the entire coal research community as kind of a foundation upon which the research that is being conducted today is built. It is impossible for you to look at Fuel, one of the leading journals, for example, in which coal research is reported, without seeing reference upon reference to samples that have been derived from the sample bank, together with the associated data, so that what you are doing by destroying this facility is dealing a deathblow in many ways to not just Penn State and its coal research activities, but to coal research in general across the country.

One of the interesting facts associated with our development of this bank has been the experience of realizing that fully 75 percent of the people that come to us for samples on which to build their research do not know what they want to begin with. In other words, this requires an interaction between university personnel to assist them in developing the information and the materials that they require for their research, so this has the potential of having impact far beyond the Penn State realm. As to what will happen to the sample bank and data base, this of course only time will tell. I hope it continues vigorously for the next 20 years. In my opinion we are about halfway through the job of amassing the materials that the coal research community needs. Our experience is quite clear. The need is across the board. The samples and data sort out to being requested about 50 percent by academic institutions, about 40 percent by industry, and about 10 percent by governmental agencies, so indeed we are serving the entire spectrum with this support system.

Mr. WALGREN. Our friends from Holland did not sense that there might be a distress sale of any of our national assets, did they?

Dr. SPACKMAN. Well, the reference that Dean Hosler made was to the fact that the people in Holland, recognizing that they are going to utilize a much larger quantity of coal in the future than they are at the present, have decided first they will not open their own coal mines. Instead, they will obviously purchase the 30 million tons that they are going to require by the end of the century, so that they have set about the business of learning something about the resources that they might be able to tap, so they are creating what they are referring to as a world sample bank.

They have asked Penn State to participate with them in the development of this. One of our roles will be to collect samples of American coals that will reside in their bank, and the intent here is to have our data base, and the reason that the man is coming today or is here today is to begin to structure their data base in the same manner that ours is structured, so that the two can be tied together via satellite, thereby enabling us to enjoy, if you will, a free flow of information concerning coals around the world as well as coal samples around the world, which again perhaps carries more importance than appears on the surface, because we can learn a great deal from, for example, the Southern Hemisphere coals, which are quite dissimilar from ours, but they will enable us to learn a good deal about ours through their investigation.

Mr. WALGREN. I know that on the congressional level the staffs who are the real experts in these areas do also value the coal data bank very highly, and I am hopeful that we find a way to maintain those functions.

Mr. ERTEL. I think you have covered everything I wanted to cover, Mr. Chairman.

Mr. WALGREN. I only want to say in closing that we keep our eyes wide open, and keep asking ourselves the question: is this really necessary? What is truly happening to the resources that are not being directed in these areas that we can reach broad agreement is of great value and importance to the country. I am afraid the country is under presently a misinterpretation of what is happening to those resources. Those resources are being transferred, not returned to the taxpayers, but they are being transferred to defense spending.

Now defense spending has some values, but there are also limitations on that, and I hope that our public will have its eyes wide open to what we are giving up and what we are trading it in for.

Let me express on behalf of the chairman of the full committee, Mr. Fuqua, and other members of the committee, appreciation for the time and views that you have brought to the committee. We will do our very best to make sure that your efforts are picked up on and considered and the efforts that you made at these hearings are not forgotten about. Thank you very much.

Mr. **Ertel**. Thank you again.

[Whereupon, at 1:05 p.m., the subcommittee was adjourned.]

COAL RESEARCH

MONDAY, AUGUST 23, 1982

House of Representatives,
Committee on Science and Technology,
Subcommittee on Energy Development and Application,
Washington, D.C.

The subcommittee met, pursuant to call, at 10 a.m., and 2 p.m., in the Salon D'Or Room, Airport Hilton, 10330 Natural Bridge, St. Louis, Mo., Hon. Harold L. Volkmer presiding.

Mr. Volkmer. Good morning. Our hearing today on coal research is the third in a series devoted to this subject. Our objective is to determine where should Government R&D programs go from here.

Many of the witnesses today have been constructing projects which use coal to produce a variety of products. This experience makes for an acute awareness of technological issues. We look forward to drawing on this experience to determine what past programs have been most beneficial and what future programs are needed to overcome the technical issues that have been identified.

We recognize that over the years coal has been used in a variety of processes to make a variety of products. There has been much more art than science used in developing these processes. A good example of this is the combustion of coal which was identified in our previous hearings as an area where we lack technical understanding of the process.

Consequently, we are looking for a system of values based on your experience and judgment as to what specific Government activities should be pursued to develop the needed technology.

We welcome the witnesses today to St. Louis and this hearing. We look forward to drawing on their background and experience to help guide the future Government activities in the fossil energy area.

It is with great pleasure that I introduce the members of the first panel: Mr. Dave Fuller of CoaLiquid, Inc.; Dr. Gerald T. Peterson of Allis-Chalmers Coal Gas Corp.; Mr. Jeff Naslund of MAPCO; J. Frederick Weinhold, TVA; and Mr. Bob Wallace of Peabody Coal Co.

Before going to our witnesses, I would first like to recognize our colleague from Illinois who is very interested in this subject matter and has worked very diligently in the Congress for many years in this area, Mr. Paul Simon, from southern Illinois.

Mr. **Simon**. Thank you, Mr. Chairman. It is a pleasure to join you and Bob Young here. I applaud your holding these hearings.

Let me just make a few comments before we hear from the witnesses. No. 1, where we are going on R&D in coal, we are going downhill. We have been going downhill as far as Federal assistance to research.

If the Federal Government had spent one-tenth as much on coal research as we have spent on nuclear research, we would not be in the energy dependent status we are in today. We have had lip service for coal research from the three administrations that I have been in Congress with. We have had very little action. I recall when President Carter gave a talk on energy in which he said we have to really push coal; and I remember the Associated Press reporter called me and said he wanted to know my comment.

I said I hope the Secretary of Energy listened to the speech. Jim Schlesinger was a nice man; I loved to have him as a neighbor, but he was no more interested in coal than I am in "rock and roll" music. We simply have to be moving ahead. We are not moving ahead as we should be. Second, we have to be somehow—and I don't know if this is a jurisdiction of your subcommittee or not, Harold—but somehow we have to be providing incentives for industry to be using the present technology. It is not only that we need research, but we have to be utilizing the research that we have. We are not doing that very effectively.

I note that we just passed a Federal military budget, a portion of which is going to a rapid deployment force to "safeguard our oil interests in the Middle East." I favor having a rapid deployment force; I do not want to be misunderstood on that question. But the way to safeguard our interests is to be less dependent on Middle Eastern oil, and we are not moving in that direction as far as utilization of coal is concerned.

Finally, Mr. Chairman, I think we need to have a great deal more Government/private sector cooperation in the coal research area. The three areas where the United States is really successful today in the export field have had close private sector/public sector cooperation. That is agriculture, aerospace, and computers. I hope we can move ahead. I see us not moving ahead as we should be. I applaud you for holding the hearings, and I hope you can help to nudge this country in the direction we ought to be going.

Mr. **Volkmer**. Thank you very much, Paul. I would also like to introduce the chairman for this afternoon's hearings. Most of you probably know him. You are actually sitting in his district right now. He is Congressman Bob Young from the Second District of Missouri. Bob has been most active in this field and is very active in the subcommittee and in the full Committee on Science and Technology. He is very interested in the research and development program on energy. I think he, too, like I, agree with Mr. Simon we need to get more energy independent.

To start with, our witnesses, as their names appear, may read their statements which will be made part of the record or they may summarize them, either way.

Mr. Fuller.

STATEMENTS OF DAVID FULLER, VICE PRESIDENT FOR MARKETING, COALIQUID, INC., LOUISVILLE, KY.; GERALD T. PETERSEN, PH. D., VICE PRESIDENT AND GENERAL MANAGER, ALLIS-CHALMERS COAL GAS CORP., MILWAUKEE, WIS.; J. K. NASLUND, MANAGER, INTERNATIONAL COALSALE/PROJECT DEVELOPMENT SYNFUELS, MAPCO, TULSA, OKLA.; J. FREDERICK WEINHOLD, PROGRAM MANAGER, COAL GASIFICATION PROGRAM, TVA, CHATTANOOGA, TENN.; AND ROBERT T. WALLACE, VICE PRESIDENT, CORPORATE PLANNING, PEABODY COAL CO., ST. LOUIS, MO.

Mr. FULLER. I would like to ask my statement be made part of the record in its entirety. I will briefly summarize it for the committee.

I am Dave Fuller, vice president of Marketing for Coaliquid, Inc. We are in the coal slurry fuels business. We make a coal-oil mixture and have active programs in coal water, coal beneficiation, and other slurry fuels.

The Energy Security Act defined our basic goals and objectives regarding our energy policy. However, the implementation, I feel, has been somewhat misleading and confusing over the years.

In order to have an effective program, I believe we need five basic elements:

First, we need a conservation program to provide incentives for all to conserve energy. We need an alternative energy program or a synfuels effort; an environmental program to work hand in hand with energy development; and a transportation network. We must constantly improve our transportation efforts in moving energy to where it is needed. We also need the continued development and expansion of our domestic resources: coal, oil, and natural gas.

Presently we have two domestic resources unregulated and one regulated. In order to provide for true economic development of our domestic resources, I believe they all need to be unregulated.

My specific comments today will relate to coal and coal R&D. However, I feel that we must keep in mind our overall energy goals and objectives when we comment on any specific element. I would like to touch on four key areas: (1) coal beneficiation, (2) coal slurry fuels, (3) analysis and recommendations for Government assistance, and (4) transportation of coal.

By coal beneficiation, I mean the deep cleaning of finely divided or pulverized coal, not just washing. I believe that coal beneficiation should be the top priority of DOE fossil energy. Approximately two-thirds of our domestic coal is high sulfur and high ash coal which is defined as poor quality. If we can find ways to clean up this coal, we can significantly reduce the cost of converting to combustion units to burn coal.

There are several technologies available today, mechanical and chemical, that are coal beneficiation oriented. They do work. However, we need additional research and development to bring the most economic ones to the marketplace, and to make sure that we are not overlooking some new ones.

I have on this chart an example of one technology which is a mechanical technology for beneficiating coal. This particular technology is called Spherical Agglomeration. Basically what you do is pulverize the coal to 200 mesh, about the consistency of face powder. Then it is slurred with water; 70 percent water, 30 percent coal. Next, a light oil is added in the next in stage, a kerosene or No. 2 oil. Next, you move into high speed mixing, like a big blender of some sort. The carbon particles of the finely divided coal have an affinity for the oil and agglomerate into large clumps. You pass the entire mass over a screen, washing out the ash and sulfur with the tailings. What you have left is a cleaner carbon particle with the oil attached to it.

I would like to point out that this is just one method of many in the marketplace. When you clean coal, you can serve various markets with it. Coal can be burned directly as pulverized coal if it is clean, and you can significantly reduce the cost of emission control. The coal can be used in a slurry. Mix it with water, or oil, and burn it as a coal slurry fuel. We seem to spend billions on gasifying coal and liquifying coal but overlook the simple, near-term technologies of merely beneficiating it and burning it in a liquid slurry or as a solid.

The next point I would like to touch on is coal slurry fuels. They fit into our overall energy plan in two areas. Coal oil mixtures are defined as a synfuel, in the Energy Security Act. However, I think they more appropriately fit in the area of "expansion of our domestic resources," or more specifically, increased coal utilization. The Department of Energy in 1979 made a significant quote, that said, "coal in liquid-phased suspension is one of the few near-term technologies to help alleviate our Nation's energy problem." Very true.

Some of the benefits of coal slurry fuels are as follows: they are handled and transported as a liquid, not a solid, they are burned through liquid fuel delivery systems. Therefore, you can bypass the problems of handling coal as a solid; coal piles around urban areas, large conveyer systems, etc.

I would like to view the slurry phase of our energy program in three parts: Phase 1, coal-oil mixtures. They are ready today. When fully developed educated users would be in the marketplace with converted units along with educated producers to supply them. Phase 2, coal beneficiation. We must have clean coal for coal slurries the same way we need it for direct pulverized coal firing. Phase 3 is coal water. This is an R&D program under-way today. We just back out the oil; therefore improving the economics and replacing more oil. In part 1, coal-oil mixtures, it has been said we can replace over 300,000 barrels of oil a day.

My third topic relates to Government programs. To summarize the past Government programs, I think it is best to say they have been confusing and frustrating. We have had specific programs for coal-oil mixtures, cooperative agreements, the Federal Non-Nuclear Act, and Defense Production Act. These have been on again, off again depending on what stage of the budget process we have been in. Then, in the final analysis, the Government said: let's just transfer all of them to the Synthetic Fuels Corporation and let them deal with the problem. There have been changing goals and objectives throughout the history of most of these programs.

There is one particular program I would like to highlight today that I believe should be used as a model for Government programs. It was a very good one. It came out in 1980. The Department of

Energy introduced a program called the PON, program opportunity notice. This program was for burning coal-oil mixtures in various combustion units in order to obtain the necessary data before full commercialization of COM can take place.

The money was not for the producers. It was for the users. It was a cost-shared program where the users were to put up 50 percent of the dollars and the Government the other 50 percent. There were various categories of combustion units so a wide variety of combustion data could be obtained. The entire program was approximately $20 million. It was an excellent program, but it was canceled. It was canceled along with a lot of other programs, termed as "demonstration programs."

I believe the main reason for its cancellation was because the word "demonstration" is a term that has fallen on considerable disfavor under the current administration. The program was not viewed on its own merits. It was just canceled with other programs called demonstrations.

There is a school of thought that says the Government should not be involved in demonstration programs. I do not have a problem with this belief. However, I have a problem with the definition of "demonstration program." To me a demonstration program is usually a large program where the Government funds production facilities to determine whether or not a particular technology is economically and/or technically feasible, such as gasification or liquefaction. This program was not like that at all. The coal oil mixture PON was to be the final phase of R&D just prior to full commercialization of coal-oil mixtures. The market data needs to be there. Utilities and industry are not going to convert to a new alternative fuel without a history of operating data. We still do not have that data and COM commercialization has been set back 2 to 3 years.

Coal-water slurries are coming down the pike. They will be at the same point, hopefully, some day coal-oil mixtures were a year ago. Let's hope that Washington can change its thinking and provide the necessary data, that last phase of research and development so coal slurry fuels can go into the marketplace without undo delay.

My last point relates to transportation of coal. The most readily available way to move coal today is by rail. However, rail is very expensive. We need alternative methods to move coal throughout the country in order to get it to the right markets. A project my company was working on included a coal cost of $29 a ton in Utah at the mine. It was going to cost us $31 a ton to transport the coal to the State of Washington for a total cost of $60 a ton. The economics killed that project.

It costs about $30 a ton to move coal from eastern Kentucky to central Florida. We were looking at another project in Jacksonville, Fla., where coal from Australia could be laid into Jacksonville for $60 a ton. Comparable coal from eastern Tennessee would have cost $65 a ton.

We need to extend our inland waterway system and eminent domain rights for coal slurry pipelines.

Mr. Chairman, in summary, I would like to make four recommendations to this subcommittee. No. 1, enlarge the DOE budget for coal beneficiation and research and development. Second, add coal beneficiation plants to the qualified projects list under the Energy Security Act. Third, continue funding for coal slurry fuels research and development and take them to the full commercialization stage. Fourth, support the expansion of the inland waterway system and eminent domain legislation for coal slurry pipelines in order to create competitive alternatives for transportation of coal.

This concludes my comments today. I thank you.

[The prepared statement of Mr. Fuller follows:]

STATEMENT OF
DAVID C. FULLER
COALIQUID, INC.

INTRODUCTION

My name is David C. Fuller. I am Vice President of Marketing for CoaLiquid, Inc. of Louisville, Ky. CoaLiquid is a coal slurry fuels processor, and we have been in business for approximately six (6) years. We have developed, and are currently marketing, a coal-oil mixture (COM), and have active projects in coal beneficiation, coal water slurry, and petroleum coke and oil slurries.

The Congress through the Energy Security Act defined goals regarding our direction as it relates to energy independence. However, confusion has set in regarding these goals and their implementation. We must have clearly defined goals so we are all pulling in the same direction. Outdated goals and objectives should be changed or modified and then effectively communicated for all to follow.

An effective program leading toward energy independence should have the following elements:

- Conservation - well designed and implemented incentives to encourage continued development of conservation ideas, methods, techniques and innovation.
- Alternative Energy or Synthetic Fuel Program - Necessary for future energy independence.
- Environmental Program - We must not pollute our environment for the sake of energy development. We need a strong but practical environmental program to work with energy development.
- Transportation Network - We must continue to improve and expand methods for transportation of energy at reasonable

costs to areas where it is needed.

- Continued Development and Expansion of Existing Domestic Energy Resources, i.e. Natural Gas, Oil and Coal - currently we have one commodity (natural gas) regulated and the other two unregulated. In order to allow efficient innovation and true economic development, all must be unregulated.

My specific comments today are directed toward coal and coal R & D, but the basic elements and objectives of our overall energy program cannot be ignored. I would like to touch on four (4) key points:

1. Coal Beneficiation
2. Coal Slurry Fuels
3. Analysis of and Recommendations for Government Assistance
4. Transportation of Coal

Coal Beneficiation

I firmly believe that coal beneficiation should be the top priority for DOE Fossil R & D efforts. My reference to coal beneficiation here is "deep cleaning" i.e., the removal of ash and sulfur from finely divided coal.

Approximately two-thirds of the potential coal reserves located within the United States are considered "poor" quality coal, with respect to the sulfur and ash content. In order to burn this most abundant United States energy resource, domestic industry and utilities must spend vast sums of money for environmental control equipment in order to meet existing pollution control regulations.

Today, given one has enough money, there are collection devices available so that coal can be burned and acceptable environmental standards met. However, the cost is too high. Coal beneficiation processes can significantly reduce the ash and sulfur in coal prior to combustion, thereby, significantly reducing the cost of emission control.

Additionally, the waste sludge left from current effective emission control devices (which is normally classified as hazardous waste) would be reduced as a result of the removal of the sulfur and ash through coal beneficiation prior to burning the coal in the first place.

Good, cost effective coal beneficiation technologies would also allow us to utilize our less expensive, more abundant supply of high sulfur/high ash coal within acceptable environmental standards.

There are several technologies available (both chemical and mechanical processes) that will perform the coal beneficiation function. However, further price performance research and development activities are necessary in order to determine the most cost effective, practical methods.

A very small budget is currently planned for coal beneficiation (around 2 million), while billions are spent on synthetics from coal. Coal can be used as a solid by utilities and industry if the ash and sulfur are minimized. Why devote vast sums and considerable energy to liquifying or gassifying coal, without first reviewing and developing the obvious (near term) approach of beneficiation. A budget of $200 million annually should be devoted to beneficiation development and demonstration.

Beneficiating coal prior to burning it will serve several coal markets. It is immaterial whether the coal will be burned directly or used to make some coal slurry fuel to be burned as a liquid later. In any case the coal will be a cleaner burning and more efficient fuel.

Coal Slurry Fuels

Coal Slurry Fuels are key in our energy plan. They may fall into the overall energy plan under synfuels, but more correctly under, "Expansion of Domestic Resources" and more specifically under increased coal utilization.

In addition to increasing our use of coal, coal slurry fuels have some additional important benefits. These are as follows:

A. Because they are coal in a liquid media, they are handled and transported as a liquid, not a solid.

B. They are burned through liquid fuel handling systems; therefore, users are not forced into the major conversion to solid, bulk handling fuel delivery systems, which require:

  (1) Large amounts of space

  (2) Control of coal piles

  (3) Solid material conveyor systems

Coal slurry fuel development should be viewed in three (3) phases with Government participation at key strategic points.

Coal Based Slurry Fuels Phased Development

Phase I - Coal-Oil Mixture (COM) widespread usage in the marketplace.

Phase II - Coal beneficiation. Clean the feedstock coal (eliminate sulfur and ash) prior to making slurry mixtures.

Phase III - Coal Water Slurry (CWS). Remove the oil from the COM and burn CWS with clean coal.

This phased approach utilizing coal based slurries to replace residual oil in oil fired industrial and utility boilers provides many practical benefits in the search for energy independence. The objectives of the phased approach can be accomplished economically and quickly with a relatively small amount of R & D coiniciding with incentives for commercialization efforts that are already underway.

Each phase is briefly described below with its associated objectives, resultant benefits, and important relationship to the other phases.

Phase I - Coal-Oil Mixtures (COM) are the nearest alternative energy source ready for full commercialization. COM stands ready and is in the process of being expanded into the commercial marketplace. This expansion of COM will provide two key benefits:

1. The potential exists to replace over 300,000 barrels of oil per day in the near term as it relates to the USA's energy picture.
2. Through expansion of COM into the marketplace, an educated base of coal slurry users will be developed. Users will have made their conversions and proficiency will be developed in handling and burning coal slurry type fuels. Producers and suppliers of coal slurry type fuels will also become widespread in the marketplace.

Phase II - This phase is Coal Beneficiation described above. This phase will provide new markets for high-sulfur, high-ash coal and, at the same time, reduce coal feedstock costs for the resultant coal slurry fuels.

Phase III - Utilize coal-water slurries (CWS). This is also an R & D effort requiring significant government participation which is currently underway in the USA. Take the oil out of the coal-oil mixture (COM) slurries. This phase is 4 or 5 years away, but very significant. Obviously, additional oil usage can be reudced and the resultant fuel cost becomes even more economical for users of the fuel.

Government Programs and Participation

Goverment programs in Energy related areas have, for the most part, been confusing and frustrating.

The support of specific COM programs, e.g. Cooperative Agreements, the Federal Non Nuclear Act and the Defense Production Act have been on again, off again; then transferred to SFC with constantly changing objectives that sometimes do, and other times do not mesh with the original Energy Security Act goals.

DOE Fossil developed an excellent program for coal-oil mixtures (COM), a coal slurry fuel, in 1980. This program was a solicited program opportunity notice (PON) for industry and utilities for conversion of various size and categories of combustion units to burn COM, thus providing valuable data over extended periods for the marketplace. This step is necessary before mass commercialization can take place. Industry simply must know test results from other industry before they are willing to risk switching to a new alternative fuel. The basic features of this program were as follows:

- The funding was for users of the fuel, not producers. Therefore, the government was not commiting large sums for COM production facilities.
- Various categories of combustion units were to be selected so as to provide a wide variety of sound commercial data based on actual experience over extended periods of time.
- It was a cost sharing program where the government only supplied 50% of the boiler retrofit funding.
- It was only 22 million of government funding for the entire program.

Unfortunately, the program was cancelled. The program was the final step necessary to enable COM to become widespread commercially. COM commercialization has been set back 3 to 5 years. The COM industry needed that data and still doesn't have it.

The main reason for cancellation of the program was due to it being defined as a "demonstration," a characterization that met with disfavor under the current administration. Since the amount of money was small it was not viewed on its own merits, but cancelled along with other demonstration programs. Currently, there is popular thinking that says "the government should not be in the demonstration program business." I do not disagree with that philosophy. The definition of "demonstration program" is where I contend the error is being made, and, this is something we should investigate and correct.

A demonstration program should be viewed as the government funding (usually large) production facilities of high risk technologies such as liquefaction or gasification plants to prove and/or determine if the technologies are viable. The PON program for COM did not fit that mold. This program was the final R & D phase to provide the marketplace with the required data just prior to full commercialization. No money was to be allocated for production facilities. The total amount was small, but the pay off extremely large, i.e. matching 50% from those users selected in the PON; production facilities constructed by suppliers with private capital, plus a firm groundwork laid for full and widespread commercialization of COM.

An excellent program that could have generated hundreds of millions in economic activity, at a cost of under $20 million was lost.

Coal-water slurries (CWS) are now in the R & D phase at DOE Fossil. At some point in time in the future CWS, hopefully, will proceed to the same point where COM was under the PON described above, i.e. the marketplace will need operating data. Let's not make the same mistake again. In order for full commercialization to take place the same type of production and usage data will be necessary. This is the final phase of R & D and the right place for government assistance.

Transportation

Nearly every aspect associated with the coal industry shares the common problem of the need for more economical/competitive alternatives for moving coal. This holds true regardless of how the coal is to be used. The transportation element is key to the future of coal utilization.

Presently, rail is the most accessible way to move large quantities of coal to the greatest variety of locations. The facts are simple. Railing coal is very expensive and the future looks to bring even higher costs. We need competitive, cost effective alternatives such as: water ways to key markets (i.e., the Tenn Tom project) and coal slurry pipelines.

For example, a coal-oil mixture (COM) project my company was contemplating in the state of Washington was simply not economically feasible due to the rail rates of moving coal from Utah to the state of Washington. The coal cost $29 per ton at the mine in Utah, but the transportation cost of $31 per ton to Washington (bringing the total cost of the coal to $60 per ton) killed the project.

It cost approximately $30 per ton to move coal from Eastern Ky. to central Florida by rail. In another instance we found that we could lay coal into Jacksonville, Fla. from Australia for less money than from Eastern Tennessee. The total cost for the same quality coal delivered to Jacksonville from Australia was $60 per ton. The total cost for an equivalent coal from Eastern Tennessee was $65 per ton.

The major portion of this cost is rail transportation. I would like to encourage the Congress to support legislation to promote competitive alternative methods for transporting coal, such as; additions to the inland waterway system and coal slurry pipelines.

Summary

In summary, my recommendations to this subcommittee are:

1. Enlarge the DoE budget for coal beneficiation R & D.
2. Add plants for beneficiating coal to the qualified projects list under the Energy Security Act.
3. Continue funding for coal-slurry fuels R & D to take them to the commercialization stage.
4. Continue support for waterway expansion projects such as the Tennessee-Tombriggbe and eminent domain legislation for coal slurry pipelines in order to create competitive alternatives for transportation of coal.

Thank you very much.

Mr. VOLKMER. Before we go to questions, we will hear from the rest of the panel.

Mr. Naslund.

Mr. NASLUND. Mr. Chairman, members of the subcommittee, I will read my statement.

I am J. K. Naslund, manager of project development for MAPCO synfuels and international sales manager for MAPCO Coals. MAPCO [MDA/NYSE] is an integrated energy company involved in the exploration, production, processing, and marketing of oil, gas, gas liquids, and other petroleum products; mining and marketing of coal and precious metals; and which operates the Nation's largest gas liquids common carrier pipeline system and the world's first anhydrous ammonia pipeline. Also, MAPCO produces and markets liquid plant food and sonic instrumentation.

MAPCO coals is a major nonunion producer of Eastern and Illinois Basin coals whose reputation for safety and productivity is well known. Recently, a study published by Coal Outlook ranked MAPCO as the safest mining company in the industry. In synfuels MAPCO has been evaluating a project in White County, Ill., to produce methanol from coal and, through its Delta Refining subsidiary, has been participating in the Memphis medium Btu gas project. Both projects are under review by the U.S. Synthetic Fuels Corporation. for financial assistance. The Memphis project was a DOE demonstration project; White County has been funded solely by MAPCO.

My comments this morning will have three parts:

First, general observations on historical Federal coal research and development programs with some future recommendations.

Second, suggestions for a framework to prioritize coal R&D in extraction, preparation, and transport.

Third, proposals of objectives for coal R&D related to processing, conversion, and cleanup.

Before proceeding, I would confess to this committee that may background is not technical. I was trained as a political scientist and as an economist. What knowledge I have accumulated derives from my experience in the industry over the past 6 years. Therefore, I trust you will keep my educational prejudices in mind.

Research and development for coal has been relatively unguided for the past 15 years. Certainly some change of activity must be anticipated, since the congressional budget process varies from year-to-year, as it does between administrations. However, it would appear that effectiveness in R&D policy may lie in achieving a consensus between industry, Government, and university on the areas to be funded. Planning extensively to insure specific project definition is needed prior to spending money. Then, competent personnel executing standardized project management systems must perform oversight. Such an approach would assure obtaining a better return on the taxpayer's investment.

Viewed historically, a great deal of progress has been made, both in research and development. However, the chronological record of Government programs is haphazard. In order to focus the program objectives, considerable planning needs to be undertaken. Government must enlist private industry expertise, not meaning consultants, but those companies which have built and operated coal processing plants, to determine what problems need to be solved. University sources should also be used to form a consensus on what problems have to be solved. Any other policy focus than developing a consensus on problems and solving those problems, steps from the realm of coal research and development into energy or industrial policy. The result will be little progress in realizing the most economic means of mining and utilizing coal.

A major criticism which has been leveled against federally sponsored energy R&D is that the programs have been badly managed. To use an industry term, the programs were not well executed. In part, the regulatory system is to blame, since reform of administrative legal procedures in Federal agencies is long overdue. Chiefly, though, qualified people are not usually found in Government departments that have responsibility to manage the programs. Few administering major DOE programs, for example, have had energy project management experience. it is questionable, at this stage, whether the DOE is staffed adequately to manage major R&D programs. Thus, prior to funding efforts, it would be of particular use to insure professional staffing for management of coal research and development.

The major deficiency of these government-sponsored coal R&D programs appears to have been the problem of project definition. Certain projects, presumed to have commercial worth, are selected. The criteria are combinations of political pressure, policy directions, and personal appeal. Only after this come considerations of technical merit. Thus, the only way government can reform this practice would be to define the problems and the projects more specifically. The disadvantage of this approach is that it has little political glamour. Coal utilization involves some dirty and dreary stuff. The advantage of this approach is that more advances could be made possible with lower capital outlay. Further, the prospects of program cost overrun will be reduced because the scope of work can be carefully defined. Such programs are easier to manage and will contribute more to the commercial utilization of coal than some major projects.

Performance is a major economic and technical risk attending coal research and development projects. Those factors that affect coal chemical processes are the areas that should be investigated by the government. By targeting problem areas and solving those problems, government R&D in coal could, it is hoped, assist the industry through more technical difficulties while avoiding the commitment to project duplication or massive commitments for dubious projects.

The best recommendation I could make would be to follow the example of the Atomic Energy Commission, assembling a task force of industry, universities, and government to determine first the problems that need to be solved. Such a group could also assemble a 10-year plan for coal research and development. With consensus formed and a plan prepared, the objectives for programs would be better defined. Once implemented, such a plan could more reasonably pace coal research and development and reduce the major swings in funding which have occurred over the past 5 years.

This type of program would probably attract capable people from industry because it has some integrity and objectives. This plan would reduce dependence upon consultants for policy development and facilitate more dollars ending up in actual research and development. Also, interchange of personnel between industry and government should be encouraged since both may benefit. A final advantage of this approach is that such a consensus would be able to better deal with changes in political weather.

Priorities for coal mining R&D. Simple technologies are the most useful. An example is the development of the AES, automated extraction system. When tested by Consol, the electronics, though complex, were modular, easy to maintain and operate. All of the other mechanical features were so large and heavy that it was too big to enter the mine space and was only good for mining vertically, since it sank every time it was operating, due to the weight. Solving basic problems in mining is the best contribution Federal R&D could provide in this area, but technology cannot solve all the problems.

From a mining standpoint, several basic problems are:

One, treatment and economic utilization of acid-bearing water. The problem is to treat the water, such that the iron, sulfur, and carbonics that are found in this water can be recovered to some economic use.

Two, shaft-sinking is the longest lead task of mine construction. Techniques for this have not varied for hundreds of years. Anyone got a better mousetrap?

Three, capture of methane gas for concentration and productive use in order to economically utilize this resource.

Four, handling of mined coal for transport to the surface with greater efficiency.

Five, techniques to stay in the coal seam longer. Remote-control and video-assisted mechanics to preserve safety yet improve productivity might be fruitful areas.

Six, basic research on the spontaneous combustion of coal with respect to gob piles, storage piles, barges, and vessels. Ways to control such hot coal would be useful.

Seven, proof of diesel engine safety could contribute to mining equipment reliability. Ventilation would not appear to be the main problem, as other mining industries rely upon such engines.

Contributing to safety and prouctivity is not an appropriate single focus in R&D. An example of faulty technology focus is the self-contained safety oxygen pack. That gear is quite heavy and uncomfortable, and has led to a good number of accidents, including some, one hears, involving Federal mine inspectors. MAPCO's track record in both areas is due to communication, valuing people, and giving attention to detail. Education and awareness, not technology, are the answers to safety and productivity. Incidentally, those two go together. Productive mines tend to be safe mines.

The focus of effort on problem solving has been governed by making innovations pay off. For MAPCO, as for most of the industry, operating coal mines is a full-time job. Only those large companies with resources to spare can afford R&D. And in most R&D proposed by the government, the big companies are the ones that will reap benefits. Such R&D does not interest MAPCO too much because the technologies are, for the most part, mature. Constraints are not technical as much as legal, social, and economic.

In the area of coal utilization, the goals of government R&D have been much too broad. The approach, for example, in synfuels tends to be governed by policy trends to develop new technologies for using coal to meet production goals. Synthetic fuels began as a modest undertaking to provide for several commercial scale projects to set a limit on OPEC oil prices. We are just now reverting to that perspective, which is all the market will bear. Developing standards, criteria, strategy, and planning is what the SFC is doing now, before spending money, that the DOE should have done in years 1976–80. Had that been the case we might be progressing in several areas, instead of pruning necessarily overgrown programs.

The DOE—or the Department of Commerce now—is not in a position to commercialize technologies. Two lessons learned on SRC II are that government involvement increases costs and that technology transfer is all but impossible. Due to bureaucratic mechanics of cooperative government/industry ventures, projects cannot be brought in on time or budget. Also, confidential information questions are too complex to deal with before, let alone after, the DOE tries to divide the patent pies equitably among government, industries, and international participants. The government is perceived as an unwieldy and unreliable partner. Risks of doing business with the DOE are perceived by energy companies as greater than those of the inherent technical and capital risks in synfuels projects. After all, who but the Federal Government can terminate a contract by reason of convenience.

Objectives for coal utilization R&D, therefore, ought to be those that assist the private sector with key technical problems, not those that swell the coffers of newsletter publishers and government contractors.

In the area of coal research and development, several problems arise in the use and conversion of coal:

One, solids handling as they relate to variable coal characteristics for feedstock use and varieties of plant design.

Two, prevention of abrasion through research both of materials as well as design.

Three, flow of solids, both from the control as well as instrumentation standpoint.

Four, reduction of impurities in process streams through the study of basic organic chemical reactions.

Five, extension of catalyst life through prevention of impurities build up.

Six, ash or solid waste quality studies to prepare for deposition or economic use of such material.

Seven, corrosion and erosion resistant process and materials research

Eight, intermediate technology assessment to confirm scale-up and economies of risks.

Nine, coal combustion studies for temperature and pressure to assess material and structural mechanical design elements of elevated temperatures and pressures.

Technology development for coal use has emphasized new concepts of processing coal. The objectives that have just been summarized represent those technical deficiencies which contribute to poor performance. Reliability of operation is the key contributor to economic viability. Another concern is that projects try to incorporate too many new technologies at once, increasing the technical risks substantially. Cost overruns can turn the investment sour. Also, the experiences of different projects have not been sufficiently documented in a single data bank available to the public, so that conversion processes could be cataloged and rated for commercial readiness. Whatever happened to COALCON?

The major problem in utilizing coal, however, is not currently viewed as a technological problem. Capital formation and recovery are the basic problems, and the real culprit is the long time of construction, 4 to 6 years. Converting coal may be a manufacturing problem, whereby modular construction and shop fabrication can accelerate capital recovery. Construcitng rapidly plant components or self-contained plants is the means to make the synfuels industry competitive, not by inventing a new process. In fact, much of the advance in coal technology has occurred due to oil processes applied to coal. Implied here is that decreasing construction time is a manufacturing problem, not a chemical engineering problem.

In concluding, I would like to talk about the market situation for coal and synfuels, since, in the last analysis, the consumers have the vote.

Coal's primary domestic use is for the generation of electricity. Historically, as energy prices have risen, electricity's share of the energy market has increased. Consequently, increases in the price of energy would lead to more coal use. Because coal-fired electric production has a technical constraint that is environmental, it is unrealistic to expect much innovation in such use. Rather, increased coal production will come as an indirect result of decontrolled energy prices.

For export of coal, U.S. production must be made more competitive if tonnage going to the international markets is to grow. There is stiff competition from Poland, South Africa, Australia, and Canada. Three economic components govern this business: mining, transport, and ports. Technological improvements in these areas are unlikely since all three are mature industries. Thus, incremental economic improvements are all that should be anticipated. further, severe political, social, and financial problems exist which will decrease the likelihood of significant change. Perhaps the best hope for exporting coal may be to develop the means to trade coal in liquid form.

From the demand side—that is, speaking of coal utilization—the markets for synfuels are uncertain. Those given the earliest changes were those, like oil shale, that could fit as a feedstock for the oil industry. However, with the glut of petroleum, the competitiveness of synfuels is questioned. Coal-based synfuels depend upon the acceptance of and the size for products. Synthetic gas and methanol are the most attractive products, in this regard. Technical work in the transportation, industrial, residential, and power generation applications that make more economic and efficient use of those two products would contribute to increased coal consumption. If the synfuels market is created—where technical innovation is more likely—then production will follow. This is not to overlook the opposition to such developments by major petroleum producers, nor to underestimate the infrastructure development required. MAPCO views synfuels as a risk management problem, where market development must precede or at least coincide with production investment. Our company is by origin and outlook a marketer of liquid energy. It is in this area that we look for research and development in coal to yield the most profitable results.

[The biographical sketch of Mr. Naslund follows:]

JEFFREY K. NASLUND

Manager, Project Development
MAPCO SYNFUELS, INC.
International Sales Manager
MAPCO COALS, INC.

Tulsa, Oklahoma

Born:

Glendale, California

Education:

Claremont Men's College, Claremont, California
B.A. *magna cum laude*, Political Science/Economics - 1972

Princeton Theological Seminary, Princeton, New Jersey
M. Div. Social Ethics - 1975

Fletcher School of Law and Diplomacy,
Medford, Massachusetts

M.A. International Business/Energy Economics - 1976

Business Experience:

International Sales Manager - MAPCO Coals, Inc., Tulsa, OK
January, 1982 to Present

Manager, Project Development - MAPCO Synfuels, Inc., Tulsa, OK
January, 1981 to Present

Director, Program Development - SRC International, Inc., - Gulf Mineral Resources, Denver, Colorado, July, 1979 to November, 1980

Senior Financial Analyst - Foreign Exchange Group - Gulf Oil Corporation, Denver, Colorado, August, 1978 to July, 1979

Senior Associate - Corporate Planning Group - Gulf Oil Corporation, Denver, Colorado, March, 1978 to August, 1978

Associate - Corporate Planning Group - Gulf Oil Corporation Denver, Colorado, June, 1976 to January, 1977

Mr. **Volkmer**. Thank you very much, Mr. Naslund.

Dr. Petersen, we are happy you were able to join us. Before we start your statement, I would like to recognize our colleague and good friend from the State of Wisconsin, who has just been able to join us. He just flew in. He is an outstanding critic of many of the energy programs and is a very outstanding member in his work on the Science and Technology Committee, Jim Sensenbrenner of Wisconsin.

Mr. **Sensenbrenner**. Thank you, Mr. Chairman. I would like to apologize for being late today. That wasn't my fault. That was the air traffic controllers delaying my incoming flight. So what else is new?

This is a very important hearing today because we in the Congress are trying to grapple for cost effective solutions to the alternative energy problem. When the energy crisis first came upon us, I think the reaction of Congress was merely to solve the problem by throwing money at any idea that came along that might have had merit. Now that we are in a budget crunch and trying to get hold of the deficit, the number of dollars available for various kinds of energy alternatives, including synthetic fuels, are getting fewer and fewer as time goes on.

That is why we on the Science and Technology Committee are trying to figure out some way of getting more bang for the buck. I think that is why a lot of the testimony at this hearing and other hearings of a similar nature are going to be very useful when we make the decisions setting forth the priorities next year for the fiscal year 1984.

Thank you, Mr. Chairman.

Mr. **Volkmer**. Thank you, Jim.

Dr. Petersen, do you wish to proceed? Your statement will be made part of the record. You may summarize or read it.

Dr. **Petersen**. My name is Gerald Petersen of Milwaukee, Wis. I have had a little trouble with the air traffic controllers, too. Glad we are both here, though.

I have been involved in energy research and development for 25 years and am presently responsible for the coal gasification business of Allis-Chalmers, which we call Allis-Chalmers Coal Gas Corp.

This morning I would like to address three subjects relevant to the Federal fossil energy research and development program. They are ones with which I have had first hand experience over the last 15 years. I hope my testimony will be important to your constructive hearings over the morning.

First, I would like to discuss some of the barriers to cooperative Government/private sector technology efforts. Second, I plan to present a few highlights of our electric utility oriented coal gasification project which involves a 600-ton per day demonstration plant currently under construction just 20 miles northeast of St. Louis at East Alton, Ill. In conclusion, I would like to point out an important barrier to coal gas substitution for oil and natural gas in existing electric utility boilers. This barrier needs to be removed by joint Federal and State Government policy action, if we are going to have domestic fuel to replace imported oil.

Turning to the first point I wish to highlight a few of the significant barriers we feel presently preclude more effective cooperative efforts between the Federal Government and the private sector in the R&D field. Technology and data rights has been an active subject between Government and the private sector for many years. Although there has been some improvement in DOE policy, two thorny issues remain.

First, there is the standard DOE rights and data clauses that put background technology, developed under private sector funding by the contractor at risk if the private sector is involved in a cooperative effort with the Federal Government. This occurs if this background technology in any way becomes involved in the conduct of the Government contract, which is frequently difficult to avoid. This creates a huge barrier and is especially dominant for the firm that has invested a large amount of private money to develop leadership position in their industry.

A somewhat related concern is the current DOE patent policy which reserves for the Department the right to march in and seize background patents if they feel it is in the best interest of the Nation. Again, it is the firm with a substantial leadership position in an industry that has the most to lose in accepting these contractual terms and conditions. We have seen that the direct result is a no-bid response from the firm with the best ability to serve the interests of the Nation in extending the technology base. We think that that is an undesirable position and needs remedy.

Others from our company have testified in various other committees especially with respect to the patent application.

Other deterents worth noting are the annual appropriation reviews of line item multiyear contracts and the Government's ability to unilaterally redirect or terminate projects with substantial private sector funding. That makes private industry and their boards of directors extremely reluctant to commit to projects where they cannot see clearly to the end result. The track record, unfortunately, has not been very good. COALCON, Powerton, and the northern illinois coal gasification project are three examples of program redirections here in the Midwest.

I would now like to turn to my second subject, our KILnGAS coal gasification development effort. The KILnGAS process is a rotary kiln coal gasification technology which is based on the extensive kiln technology base developed in Allis-Chalmers over many decades. Some of the rudimentary parts of this process were in place at the turn of the century. In the process, a large, pressurized, rotary kiln is used to gasify up to 5,000 tons of high sulfur coal per day into a clean low Btu gas. This product is suitable for boiler fuel applications in electric utility powerplants or large industrial complexes and will cost less to produce than any of the other coal synthetics, which we think is an important consideration in the development of the timing of this single element of the total spectrum of synfuel alternatives.

We began the KILnGAS development effort in 1971. By 1974 we had a 10-ton per day pilot plant operational. Through June 1976, the end of the first bar, all the funding was internal to Allis-Chalmers. In July 1976, we expanded our effort into a basic engineering phase and launched that together with 11 electric utilities.

That phase was followed by a demonstration assessment activity leading to the current demonstration phase which is supported by Allis-Chalmers, 12 electric utilities, the State of Illinois, and the Electric Power Research Institute.

I hasten to add that in teaming with the State of Illinois, we have not encountered the barriers I noted earlier that we are concerned with in dealing with the Federal Government. In fact, I think it is largely for this reason we teamed with the State of Illinois and not the Federal Government on this project.

The KILnGAS commercial module program is summarized on the next card.

The initial application is to supply boiler fuel to Illinois Power's unit No. 3, normally an oil and natural gas fired 50,000-kilowatt unit. The coal processing rate is 600 tons per day of high sulfur Illinois coal. The $137 million total project funding is summarized by source. That covers funding through the period 1984. You can see with the substantial investment by Allis-Chalmers in this phase, $79 million, and investments in prior phases, our corporation has made a contribution of over $100 million to this synthetic fuels business.

The participating electric utilities span a wide geographic area from Maryland through the Midwest to the Southwest. Union Electric, headquartered here in St. Louis, is one of our charter utility participants that has supported the program since July 1976.

The KCM demonstration plant at East Alton, Ill., has recently passed the halfway point in its construction cycle. This photo, taken in early May, shows the ported rotary kiln gasifier and some of the gas cleaning equipment in the background. We passed a major milestone in late May when the gasifier vessel successfully passed its initial pressure test. We anticipate completion of construction by early 1983 and plant commissioning to be completed by May 1983.

I would now like to turn to my final subject, coal gasification as a replacement for oil and natural gas as a boiler fuel. First, it is worth noting that this is a major area of premium fuel use. In 1980 about 3 and 6 million barrels of oil equivalent were used in electric utility and industrial boilers respectively. Those are the areas of those two pie charts. The 3.9 million barrels a day of oil represent about 25 percent of the 17 million barrels of oil a day consumption in 1980. The 5.2 million barrels a day of gas represents about half of all natural gas consumed in the United States. Low Btu coal gas does offer an opportunity to replace this significant quantity of fuel used in our country.

Our analysis indicates there is a maximum potential to replace about half of these fuels. A realistic economic analysis of the individual boilers will undoubtedly lower the achieveable fraction to less than half of this potential. However, even this is a major national opportunity. It is one we think deserves a significant amount of attention.

Fortunately, there is also a substantial economic incentive to consider this application as well as the favorable balance of payments and supply security to our national energy picture if this change were made.

This bar graph shows our estimated annual savings for a 400-megawatt boiler converted to low Btu gas from oil in 1987. That would be the first year we could bring a plant on line if the construction commitment were made in late 1984 after successful operation of our Wood River plant. In our analysis, we assumed 9 percent escalation of oil and coal prices which is somewhat near the anticipated inflation rate during this period of time. You see the savings per year range; in the first year $20 million; in the fifth year $70 million. The analysis shows capital payback is achieved in only 5 years.

Our concern is that Government regulatory control presents a significant barrier to electric utility management decisionmaking in this area. Current State and, in some cases, Federal regulatory control dictates that any fuel cost savings immediately pass from the utility to its ratepayers. This was a mechanism intended to handle the rapid increase in oil prices that have hit in the last decade. It also works the other way. It immediately insists that any savings be passed on to the ratepayer. This clearly eliminates the incentive for electric utility risk taking in a project to replace their premium boiler fuel with a coal gas supply. Their stockholders do not have a return mechanism to base and offset the risks involved in this type of project.

We, and a few enlightened State commissions, are recommending that there be a change in regulatory policy that would allow the electric utility stockholders and ratepayers to share the fuel cost savings. The State of Florida is one area I am aware of where this is being discussed with the utilities that are major oil burners. The formula would need to provide sufficient potential returns to the utility to make the project risk taking attractive to the stockholders. We also feel that if this were done, the private sector will be an effective judge of which specific projects offer the best returns for all parties.

Florida burns a high percentage of imported oil. We think this could be a significant project for the country in the next decade.

In conclusion, it has been a pleasure addressing your committee this morning. I hope you have found my comments informative and useful, even though they did not address several of the questions you circulated on August 4. I have rather limited my remarks to those areas where our experience may offer new insight. Thank you for this opportunity.

[The prepared statement of Dr. Petersen follows:]

Statement of

Gerald T. Petersen

Executive Vice President and General Manager
Allis-Chalmers Coal Gas Corporation

on

Future Coal Research and Development Needs

before the

Energy Development and Applications Subcommittee

of the

Committee on Science and Technology

U. S. House of Representatives

August 23, 1982

St. Louis, Mo.

My name is Gerald T. Petersen of Milwaukee, Wisconsin. I have been involved in energy research and development for twenty-five years and am presently responsible for the coal gasification business of Allis-Chalmers.

This morning I'd like to address three subjects relevant to the federal fossil energy research and development program. They are ones with which I have had first hand experience over the last fifteen years. First, I'd like to discuss some of the barriers to cooperative government/private sector technology efforts. Second, I plan to present a few highlights of our electric utility oriented coal gasification project which involves a 600 ton per day demonstration plant currently under construction just 20 miles north of St. Louis at East Alton, Illinois. In conclusion, I'd like to point out an important barrier to coal gas substitution for oil and natural gas in existing electric utility boilers. This barrier needs to be removed by joint federal and state government policy action.

Returning to my first point, I wish to highlight a few of the significant barriers that presently preclude more effective cooperative efforts between the federal government and the private sector in the R&D field. Technology and data rights has been an active subject between government and the private sector for many years. Although there has been some improvement in DOE policy, two thorny issues remain.

First, there is the standard DOE "Rights and Data" clauses that put background technology, developed under private sector funding by the contractor, at risk. This occurs if it in any way becomes involved in the conduct of the government contract, which is frequently difficult to avoid. This creates a huge barrier for the firm that has invested a large amount of its own money to develop a leadership position in an industry.

A somewhat related concern is the current DOE Patent Policy which reserves for the Department the right to "March In" and seize background patents if they feel it is in the best interest of the nation. Again, it is the firm with a substantial leadership position in an industry that has the most to lose in accepting these contractual terms and conditions. The end result frequently is a "no bid" response to R&D proposal solicitations from the private firms with the best ability to perform the subject effort.

Other deterrents worth noting are the annual appropriation reviews of line item multi-year contracts and the government's ability to unilaterally redirect or terminate projects with substantial private sector funding. Unfortunately, the track record has been especially poor in the field of coal synthetics. COALCON, POWERTON, and the NORTHERN ILLINOIS COAL GASIFICATION PROJECT are three examples of program redirections here in the Midwest.

I'd now like to turn to my second subject, our KILnGAS coal gasification development effort. The KILnGAS process is a rotary kiln coal gasification technology which is based on the extensive kiln technology base developed in Allis-Chalmers over many decades. In the process, a large, pressurized, rotary kiln is used to gasify up to 5,000 tons of high sulfur coal per day into a clean low BTU gas. This product is suitable for boiler fuel applications in electric utility power plants or large industrial complexes and will cost less to produce than any of the other coal synthetics.

Allis-Chalmers began the KILnGAS development effort in 1971. By 1974 a 10 ton per day pilot plant was operational. Through June, 1976 all funding was internal to Allis-Chalmers. In July 1976, an expanded Basic Engineering effort was launched with a group of eleven electric utilities. That phase was followed by a Demonstration Assessment phase leading to the current Demonstration phase which is supported by Allis-Chalmers, twelve electric utilities, the State of Illinois and the Electric Power Research Institute. I hasten to add that in teaming with the State of Illinois we have not encountered the barriers noted earlier. It is specifically for this reason that we teamed with the State of Illinois, but not the federal government, in this major fossil research and development undertaking.

The KILnGAS Commercial Module demonstration program and budget are summarized here for your review. The initial application is to supply boiler fuel to Illinois Power's unit number three - normally an oil and natural gas fired 50,000 KW unit. The coal processing rate is 600 tons per day of high sulfur Illinois coal.

The $137 million total project funding is summarized by source. Including prior phase funding, Allis-Chalmers has made a commitment of over $100 million to this synthetic fuels business!

The participating electric utilities span a wide geographic area from Maryland through the midwest to the southwest. Union Electric, headquartered here in St. Louis, is one of our charter utility participants that has supported the program since 1976.

The KCM demonstration plant at East Alton, Illinois has recently passed the half way point in its construction cycle. This photo, taken in early May, shows the ported rotary kiln gasifier and some of the gas cleaning equipment in the background. We passed a major milestone in late May when the gasifier vessel successfully passed its initial pressure test. We anticipate completion of construction by early 1983 and plant commissioning to be completed by May, 1983.

I'd now like to turn to my final subject, coal gas as a replacement for oil and natural gas as a boiler fuel. First, it's worth noting that this is a major area of premium fuel use. In 1980 about 3 and 6 million barrels of oil equivalent were used in electric utility and industrial boilers respectively. The 3.9 MMB/D of oil represents about 25 percent of the 17MMB/D of total domestic oil consumption in 1980. The 5.2MMB/D of gas represents about half of all natural gas consumed. Hence, replacing only a small fraction of this premium boiler fuel with coal gas could greatly enhance our national energy posture.

Our analysis indicates there is a maximum potential to replace about half of these fuels. A realistic economic analysis of the individual boilers will undoubtedly lower the achieveable fraction to less than half of this potential. However, even this is a major national opportunity.

Fortunately, it is an opportunity with a substantial economic incentive, as well as a favorable balance of payments and supply security advantage. This bar graph shows our estimated annual savings for a 400 megawatt boiler converted to low BTU coal gas in 1987. We have assumed that oil and coal escalate at 9% per year which is near the anticipated inflation rate. Capital payback is achieved in only five years.

Our concern is that government regulatory control presents a barrier to electric utility management decision making in this area. Current state and, in some cases, federal regulatory control dictates that any fuel cost savings immediately pass from the utility to its rate payers. This clearly eliminates the incentive for electric utility risk taking in a project to replace their premium boiler fuel with a coal gas supply.

We, and a few enlightened state commissions, are recommending that there be a change in regulatory policy that would allow the electric utility stockholders and rate payers to share the fuel cost savings. The formula would need to provide sufficient potential returns to the utility to make the project risk taking attractive to the stockholders. We also feel that were this done, the private sector will be an effective judge of which specific projects offer the best returns for all parties.

It has been a pleasure addressing your Committee this morning. I hope you have found my comments informative and useful, even though they did not address several of the questions you circulated on August 4. I have rather limited my remarks to those areas where our experience may offer new insight. Thank you for this opportunity.

Mr. **Volkmer**. Thank you very much, Dr. Petersen.

Mr. Weinhold.

Mr. **Weinhold**. Thank you, Mr. Chairman. I am J. Frederick Weinhold, manager of the Tennessee Valley Authority Coal Gasification program.

I am pleased to be here today to discuss a subject which has long been dear to my heart, coal research and development.

My remarks reflect 20 years of experience in energy technology, especially R&D, the last 3 of which have been with the Tennessee Valley Authority.

Prior to coming to Tennessee, I served in a number of energy policy and planning positions in Washington, D.C. From these, I gained a good perspective of the national effort in federally funded coal R&D as it grew from an investment of a few million dollars in the late 1960's to hundreds of millions in fiscal year 1981.

Before joining the Federal energy regulatory policy establishment, I served under Admiral Rickover in the Naval Reactors program.

It was there that I learned the need for continuing R&D and engineering to bring new technologies into operational service.

My current work brings both of these activities together—making the conversion of easter high-sulfur coal to synthetic fuel a commercial reality in the Tennessee Valley area.

It is from this perspective that I will address the concerns of your committee. The observations are mine, but with respect to matters involving TVA, are consistent with TVA policy.

Developing major new energy technoligies is a long, time-consuming task, something researchers and policymakers alike are prone to overlook.

Many of the new coal technologies I became acquainted with in the late 1960's through federally funded R&D are only now being applied to commercial practice—coal gasification, direct liquefaction, and fluidized bed combustion.

One exception is flue gas desulfurization. This technology is an add-on to commercial coal-fired powerplants, rather than a standalone system.

It has been implemented by producers of electric power including TVA, and is now in widespread commercial use.

My criteria for the success of any R&D program is the widespread commercial use of its results so that the Nation and its citizens benefit, not just researchers.

This is an engineer's definition, not a scientist's. By this criteria, few successes have been realized from the Federal coal R&D program. Given the long time to develop these new technologies and the short duration of heavy Federal involvement, this is not surprising.

Of the technological successes I know, their good fortunes were based on two common denominators—incentives and leadership. There must be a real incentive for the organization developing the technology to persevere in the face of environmental requirements and technical, economic and institutional hurdles which come up almost daily.

In the case of naval reactors, the serendipity between nuclear-powered submarines and Polaris missiles provides the Navy with a new strategic mission and therefore, a real incentive to proceed.

The Clean Air Act, as amended, provided large coal consumers—especially electric utilities—with the incentive to develop scrubbers, even though there was no financial reward.

Personal leadership is another reason for success. Men like Philip Sporn, Admiral Rickover, and Arthur Sedar, of American Natural Resources, have provided the leadership to propel improvements in coal-fired electric generation, nuclear power, and coal gasification ahead from R&D to commercial usage.

They have toiled for many years to establish projects and build the teams of experts needed to move these technologies ahead.

These examples of relatively long-term incentive, leadership, and programs contrast with many of the federally funded R&D coal activities whose fiscal and policy support rise and fall like a roller coaster.

Under such conditions, success and even solid progress is all but impossible.

Moving from these general observations from my past, let me comment on the Tennessee Valley Authority programs involving new coal technologies. TVA is playing a significant role in three coal-based technology developments—flue gas desulfurization, fluidized bed combustion, and coal gasification.

These are all at different stages of development and involve different funding sources and approaches. The scrubber work, begun in 1972 with EPA and TVA power funds, was initially aimed at developing and demonstrating a viable system for removing sulfur oxides from coal-fired powerplant stacks.

The initial work achieved its objective, but showed the shortcomings in the first-generation technology.

Using DOE, EPRI, vendor, and its own power funds, TVA has continued to work to overcome the problems with limestone scrubbers and to perfect new systems which do not pose these difficulties.

I listed the funding sources, not to confuse everyone, but because it is important to understand where the incentives for the work come. The role of appropriated funds, as contrasted with that of user or vendor funds is always difficult to define precisely, but conceptually, one can identify both national benefits and private benefits from the reduction of such improved technology to commercial practice.

Commercial installations are, of course, funded by the users such as the TVA power system, but special tests have wider funding support, and are proceeding with EPRI and national funding.

Fluidized bed combustion represents a new approach for burning coal cleanly without the need for stack gas scrubbing systems. During the late 1960's and early 1970's, developers in the United States and abroad advanced the technology to a point where it became a potential option for industrial and institutional installations.

With the help of various regulatory and tax incentives, this technology is now moving into commercial use.

TVA and others saw the potential benefits of fluidized bed combustion for utility power generation. They also realized that one could not scale up the industrial fluidized bed technology boiler to utility requirements without extensive R&D, EPRI sponsored extensive small-scale development work at Babcock & Wilcox, while TVA, using appropriated and power funds, constructed a 20-megawatt pilot plant near Paducah, Ky.

This plant has been completed and is now beginning its test program, jointly funded from TVA appropriated funds, and EPRI Funds.

On August 6th, this plant was dedicated with a number of Members of Congress present. The important thing to note is the plant was completed essentially on time and within about 10 percent of its initial budget.

I think it represents a strong statement that one can move technologies and build pilot plants without massive cost overruns and long delays.

The key point that comes out of this episode is the close coupling of small- and larger-scale testing inherent in any technology development. Larger-scale facilities provide a preview of the problems which may be encountered in commerical units, while the small facilities allow multiple solutions to be tested and evaluated quickly and at low cost.

Of course, the aim of both the TVA and EPRI is to move this promising technology to commercial sizes and applications as rapidly as feasible through construction of a 100- to 200-megawatt demonstration plant.

Here again, the development of the technology will benefit from the continuing efforts of an established team.

TVA's work on coal gasification reflects the combination of several efforts to move new technologies into commercial operation. The ammonia-from-coal project, at TVA's National Fertilizer Demonstration Center was initiated with appropriated funds in 1975. It is intended to provide the U.S. fertilizer industry with a readily available source of domestic feedstock. The plant, using a Texaco process, provides retrofit capability for existing ammonia plants and advances the status of the technology. After a long, difficult start-up period. The gasifier is now operating reliably.

The North Alabama Coal-to-methanol project, now under construction at Murphy Hill, Alabama, was initiated with the objective of demonstrating that a commercial-size synthetic fuels plant using high-sulfur eastern coal could be designed, permitted, built, and operated on an accelerated schedule and in an environmentally and economically acceptable manner.

This project was initiated in 1979 before the Energy Security Act was passed and before many of the other Federal incentives were in place. It was to be TVA-owned and operated, but with the changing budget priorities and the availability of financial support through the Energy Security Act of 1980, it was decided to transfer the project to a private industry consortium. We are trying to initiate this project and then spin it off to private industry as soon as feasible.

We chose to use proven technology for the major plant systems in order to reduce technical and environmental risks to appropriate levels, but even this required advancing technical frontiers. We tested thousands of tons of Illinois Basin coal at overseas plants to learn how U.S. coal would perform in K–T and Texaco gasifers. On the basis of these tests, we selected the commercially proven K–T gasification technology for the North Alabama plant.

The tests also provided valuable data and material for additional environmental work on plant effluents. In one area, we learned that the initial design concepts for fly dust, a mixture of ash and unburned carbon, disposal would not be suitable and that an alternative approach was needed. Further testing is under way to optimize this disposal approach. We are looking to a small-scale fluidized bed boiler as the way to get rid of the fly dust material and convert it to a benign solid waste, making electric power in the process.

Similarly, significant quantities of liquid effluent from the overseas tests are being studied to help optimize the waste water treatment system. These technological developments, while not so profound as the gasification technology itself, are an integral part of moving new coal technologies into commercial use.

I would be presumptuous to suggest specific changes in national coal R&D policy from my limited experience, but a few general observations deserve emphasis.

There is a need to focus on widespread commercial use as the goal of any technology development.

There is a need for continuing strong incentives, leadership, and support to move any technology through the maze of obstacles that confront it.

There should be multiplicity and evolution of funding sources as technologies move from one stage to another. The Government should not just start a project and pay for it the whole way. Funding commitments from the people and institutions that can play a key role throughout its whole history are needed.

There is a continuing need for R&D to resolve specific problems even with commerical or near-commercial technologies.

[The prepared statement of Mr. Weinhold follows:]

STATEMENT OF J. FREDERICK WEINHOLD
PROGRAM MANAGER, OFFICE OF COAL GASIFICATION
TENNESSEE VALLEY AUTHORITY
BEFORE THE SUBCOMMITTEE ON ENERGY DEVELOPMENT AND APPLICATIONS
OF THE COMMITTEE ON SCIENCE AND TECHNOLOGY
HOUSE OF REPRESENTATIVES
ST. LOUIS, MISSOURI
AUGUST 23, 1982

Mr. Chairman, I am J. Frederick Weinhold, Manager of the Tennessee Valley Authority coal gasification program. I am pleased to appear before you today to discuss coal research and development--a subject long dear to my heart.

My remarks reflect 20 years of experience in energy technology especially R&D, the last three of which have been with the Tennessee Valley Authority. Prior to coming to Tennessee, I served in a number of energy policy and planning positions in Washington, DC. From these, I gained a good perspective of the national effort in federally funded coal R&D as it grew from an investment of a few million dollars in the late 1960's to hundreds of millions in fiscal year 1981. Before joining the Federal energy policy establishment, I served under Admiral Rickover in the Naval Reactors program. It was there that I learned the need for continuing R&D and engineering to bring new technologies into operational service. My current work brings both of these activities together--making the conversion of eastern high-sulfur coal to synthetic fuel a commercial reality in the Tennessee Valley.

It is from this perspective that I will address the concerns of your committee. The observations are mine but, with respect to matters involving TVA, are consistent with TVA policy.

Developing major new energy technologies is a long, time-consuming task, something researchers and policymakers alike are prone to overlook. Many of the new coal technologies I became acquainted with in the late 1960s through federally funded R&D are only now being applied to commercial practice--coal gasification, direct liquefaction, and fluidized bed combustion. One exception is flue gas desulfurization. This technology is an addition to commercial coal-fired power plants rather than a standalone system. It has been implemented by producers of electric power, including TVA, and is now in widespread commercial use.

My criteria for the success of any R&D program is the widespread commercial use of its results so that the Nation and its citizens benefit. It is an engineer's definition, not a scientist's definition. By this criteria, few successes have been realized from the Federal coal R&D program. Given the long time to develop these new technologies and the short duration of heavy Federal involvement, this is not surprising.

Of the technological successes I know, their good fortunes were based on two common denominators--incentives and leadership.

There must be a real incentive for the organization developing the technology to persevere in the face of environmental requirements and technical, economic, and institutional hurdles which are confronted daily. In the case of naval reactors the serendipity between nuclear-powered submarines and Polaris missiles provided the Navy with a new strategic mission and therefore real incentive to proceed. The Clean Air Act as amended provided large coal consumers with the incentive to develop scrubbers even though there was no financial reward.

Personal leadership is another reason for success. Men like Philip Sporn, Admiral Rickover, and Arthur Sedar have provided the leadership to propel improvements in coal-fired electric generation, nuclear power, and coal gasification ahead from R&D to commercial usage. They have toiled for many years to establish projects and build the teams of experts needed to move new technologies ahead.

These examples of relatively long-term incentives, leadership, and programs contrast with many of the federally funded coal R&D activities whose fiscal and policy support rise and fall like a roller coaster. Under such conditions, success and even solid progress become all but impossible.

Moving from these general observations from my past, let me comment on the Tennessee Valley Authority programs involving new coal technologies. TVA is playing a significant role in three coal-based technology developments--flue gas desulfurization, fluidized bed combustion, and coal gasification. These are at different stages of development and involve different funding sources and approaches. The scrubber work, begun in 1972 with EPA and TVA Power funds, was initially aimed at developing and demonstrating a viable system for removing sulfur oxides from coal-fired power plant stacks. The initial work achieved its objective but showed the shortcomings in the first generation technology. Using DOE, EPRI, vendor, and its own Power funds, TVA has continued the work to overcome the problems with limestone scrubbers and to perfect new systems which do not pose these difficulties. The role of appropriated funds as contrasted with that of user or vendor funds is always difficult to define precisely, but conceptually one can identify both national benefits and private benefits from the reduction of such improved technology to commercial practice. Commercial installations are, of course, funded by the users such as the TVA power system, but special tests have wider funding support.

Fluidized bed combustion represents a new approach for burning coal cleanly without the need for stack gas scrubbing systems. During the late 1960s and early 1970s developers in the United States and abroad advanced the technology to a point where it became a potential option for industrial and institutional installations. With the help of various regulatory and tax incentives, the technology is now moving into commercial use. TVA and others saw the potential benefits of fluidized bed combustion for utility power generation. They also realized that one could not scale up an industrial fluidized-bed boiler to utility requirements without extensive R&D. EPRI sponsored extensive small-scale development work at B&W while TVA, using appropriated and Power funds, constructed a 20-MW pilot plant near

Paducah, Kentucky. This plant has been completed and is now beginning its test program, jointly funded from TVA Power funds, appropriated funds, and EPRI funds.

The close coupling of small and larger scale testing is inherent in any technological development. Larger scale facilities provide a preview of the problems which may be encountered by commercial units while the small facilities allow multiple solutions to be tested and evaluated quickly at low cost. Of course, the aim of both TVA and EPRI is to move this promising technology to commercial sizes and applications as rapidly as feasible through construction of a 100-200-MW demonstration plant. Here again, the development of the technology will benefit from the continuing efforts of an established team.

TVA's work on coal gasification reflects the combination of several efforts to move new technologies into commercial operation. The ammonia-from-coal project, initiated with appropriated funds in 1975, is intended to provide the U.S. fertilizer industry with a readily available source of domestic feedstock. The Texaco plant provides retrofit capability for existing ammonia plants and advances the status of the technology.

The North Alabama Coal-to-Methanol project was initiated with the objective of demonstrating that a commercial size synthetic fuels plant using high-sulfur eastern coal could be designed, permitted, built, and operated on an accelerated schedule and in an environmentally and economically acceptable manner. Initially, it was to be TVA-owned and operated but with the changing budget priorities and the availability of financial support through the Energy Security Act of 1980, it was decided to transfer the project to a private industry consortium.

We chose to use proven technology for the major plant systems in order to reduce technical and environmental risks to appropriate levels, but even this required advancing technical frontiers. We tested thousands of tons of Illinois Basin coal at overseas plants to learn how U.S. coal would perform in K-T and Texaco gasifiers. On the basis of these tests we selected the commercially proven K-T gasification technology for the North Alabama plant.

The tests also provided valuable data and material for additional work on environmental effluents. In one area we learned that initial design concepts for fly dust disposal would not be suitable and that an alternative approach was needed. Further testing is underway to optimize this disposal approach. Similarly, significant quantities of liquid effluent from the overseas test are being tested to help optimize the wastewater treatment system. These technological developments, while not so profound as the gasification technology itself, are thus an integral part of moving new coal technologies into commercial use.

I would be presumptuous to suggest specific changes in National coal R&D policy from my limited experience, but a few general observations deserve emphasis.

- There is a need to focus on widespread commercial use as the goal of any technology development.
- There is a need for continuing strong incentives, leadership, and support to move any technology through the maze of obstacles it faces.
- There should be multiplicity and evolution of funding sources as technologies move from one stage to another.
- There is a continuing need for R&D to resolve specific problems even with commercial or near commercial technologies.

Thank you. I would be pleased to answer your questions.

Mr. VOLKMER. Thank you, Mr. Weinhold.

Mr. Wallace, before we begin with you, my colleague, Mr. Simon, has other engagements he has to go to. I do think he has some questions.

Paul.

Mr. SIMON. Just a couple of comments and some questions for the record.

First of all, I appreciate the testimony of all four witnesses. I apologize to you, Mr. Wallace, for not being able to stay here for your testimony.

Dr. Petersen, among other things, you mentioned State laws are important. One of the things I think your report ought to focus on is that we discourage utilities from utilization of the latest techniques.

Mr. Weinhold just mentioned fluidized beds. If a utility uses Western coal and brings it out to Illinois, they can automatically add that to the utility bill. If they put on a fluidized bed or scrubber, they have to go through lengthy State hearings in Illinois and other States in order to utilize that.

The result is Illinois coal miners are out of work; the result is consumers pay more for the utility bills; and the result is we waste a lot of oil in sending railroads back and forth.

Mr. Naslund, first of all, I like your idea for a 10-year plan bringing Government, the private sector, and universities together to do it. I hope this subcommittee takes a look at that.

In the areas of research, you mentioned methane gas. I think we ought to definitely look at that.

One other area ought to be in the record, and that is the fact that railroads are starting to look at utilization of coal. I would like to see whatever is necessary with public sector private sector cooperation to see what can be done in that area.

Finally, Mr. Naslund—and I am a bit provincial here because your White County, Ill. side is in partly in my old district. You mentioned exports. It seems exports have to be a big part of coal for the future.

It can be an important part of the economy of this Nation. This is not a question right now, because I do not want to be intruding in the hearings; but I would appreciate your sending me a letter and a letter to the subcommittee for the record.

I am interested in what barriers you find to exports. Very specifically, is the Port of New Orleans long-range adequate for the kind of exports that we need. But not simply the Port of New Orleans question. I am interested in what other barriers you are finding to exports.

I thank you again, Mr. Chairman, and my colleagues. I am sorry I have to duck out on you here.

Mr. VOLKMER. That is quite all right. We appreciate your being here and joining us.

Mr. Wallace, please proceed.

Mr. WALLACE. Mr. Chairman, I am Bob Wallace, vice president of Corporate Planning for Peabody Coal Co. I might add I am delighted to see Mr. Simon here. We are still in your district.

I would like to thank the committee for inviting me to participate in this hearing. If it is acceptable to the committee, I would like to submit my comments for the record.

Mr. VOLKMER. They will be made part of the record.

Mr. WALLACE. I will summarize. I am sure you would like to get to questions as quickly as possible.

Mr. Chairman, in my paper, I outline for the sake of simplicity three types of R&D. There are many more; but just for the sake of simplicity, I call them basic research, exploratory development, and engineering development.

I then also talked about three basic categories of R&D that can take place in the coal area. They are coal mining; what I call coal utilization, which includes beneficiation; and finally, a category that I call, for want of a better descriptor, social responsibility research and development.

Given that framework, I think there are, in fact, different roles that the Government should play when we look at this matrix. From our perspective—and I will deal with basic research first—we are talking about the kind of processes and improvements in materials that Mr. Naslund discussed.

How do you develop corrosion-resistant materials? What new processes will be promising in terms of handling high temperatures, and so on and so forth.

All of this sort of activity really does not fit into any of the three functional coal categories that I mentioned.

There may be something coming out of basic research that could not only help coal utilization, but may also be of use to the Department of Defense.

I would like to leave the subject of basic research with one comment. That is, it seems to us that this is an area that is not receiving enough Federal attention. We have become too impatient in this country. We have become too imbued, perhaps, with cost effectiveness; and I think we need not to lose sight of the fact that many of the real breakthroughs that are made are done at the university or the laboratory level.

I think there has been a tendency to move away from funding this type of R&D. I strongly urge the committee to consider strengthening the Federal role in this particular area.

I would like to turn now to three coal-related functional categories that I discussed—coal mining, coal utilization, and social R&D. With regard to coal mining, it is important to remember that we have a very highly competitive industry.

We have thousands of companies. We have hundreds of equipment manufacturers. The fact that the price of coal at the mine level, increased from only $4-and-some-cents to $4.99 over a 21-year period between 1947 and 1969; I think speaks for itself.

There is a compelling need for any economic entity to go out and improve its position from a market point of view. I think that exploratory and engineering development that is aimed at improved productivity—and I am not talking about some of the other coal-mining aspects which I will cover in social R&D—I think those things are best left to the private sector.

There may be an exception, but by and large I think that basically is the right way for this particular industry to operate.

What about coal utilization? I think that situation is indeed different than coal mining.

First of all, we face very large-scale, capital-intensive projects just to prove the feasibility of many of the advanced coal utilization programs.

In addition, we have a situation where this country is tremendously dependent upon imported crude oil, and as a result, our national security is an issue with regard to coal utilization.

It is our belief that it is appropriate in this area for the Federal Government to fund research and development. Now the first two speakers talked about the problem of labels and definitions and program cancellations, if you happen to call something one thing and not something else.

Fred, I think, was the cleverest of all. He avoided mentioning the term "demonstration" at all. I will be totally ambiguous and mention it in two ways.

I think feasibility demonstrations are an appropriate role for the Federal Government to play with regard to coal utilization. What is feasibility demonstration? It could be a module; it could be a process; it could be a subsystem; it could be a pilot plant.

Whatever is necessary to give the sponsors and the Government confidence that this particular technique will, in fact, be able to be upgraded to the commercialization stage.

I do not believe the Federal Government should be in what I will call engineering demonstrations or prototype demonstrations where a large subset of a final commercialization project, is, in fact, implemented.

Let's say you have an eight-module system that you are looking at to produce so many barrels of synthetic liquids a day and you put in a one-eighth of the process and call that a demonstration program.

I do not believe when you are that close to the production phase that that kind of project should, in fact, be funded by the Federal Government.

On the other hand, we strongly support the development of a synthetic fuels industry through the use of price guarantees and loan guarantees.

I guess what I am really saying in the coal utilization area is that there is a role for the Federal Government up through exploratory or advanced development, however you might like to describe it; but at that point in time, the sponsors should have some confidence they do have a good process and they are willing to go out and stand behind it. They shall have the prospects of support in the form of guarantees from the Synthetic Fuels Corp.

That leaves my third category of research and development. The area I call social responsibility R&D. This is an area where the Federal Government, I think, clearly does have a role across the board.

Here we are talking in many cases about health and safety standards imposed by the Federal Government that may require solutions that are pushing the state of the art.

I can give you two examples that impacted our company. In the coal mining area, the Mine Health and Safety Administration promulgated a respirable dust standard recently that would have been almost impossible to meet without sacrificing a tremendous amount of productivity. Without the substantial amount of federally sponsored R&D work done on what we call a "flooded bed scrubber," which essentially takes the coal dust, as the coal is being mined, and passes it through a screen that removes the particles, we and other companies in this industry would not have been able to meet very rigid standards set by the Federal Government. It happens to be 2 grams per cubic meter.

The other area that I might mention as an example in the social responsibility R&D field involves those processes that are used to remove sulfur from coal or sulfur dioxide from flue gas.

They range from advanced scrubber technology to complete new approaches to the direct burning of coal such as atmospheric fluidized bed combustion or pressurized fluidized bed combustion.

Here again, these are developments that are being driven by the Federal Government in its role as custodian for the health and safety and welfare of the citizens of the United States.

We may argue about the extent to which these regulatory interventions should take place, but it is clear that the Federal Government does have a role to play. It is a role that I think all industry accepts. But, in addition to the Government's obligation in promulgating such requirements, I do feel that it has a supplementary responsibility to support research and development to insure that that particular social goal can, in fact, be met.

With that, Mr. Chairman, I will terminate my comments and let you proceed with the questions.

Thank you.

[The prepared statement of Mr. Wallace follows:]

STATEMENT
BY

ROBERT T. WALLACE
VICE PRESIDENT, CORPORATE PLANNING
PEABODY COAL COMPANY

Congressman Young, Congressman Volkmer, my name is Robert T. Wallace, and I am Vice President of Corporate Planning for Peabody Coal Company which is headquartered here in St. Louis.

Peabody Operations

It is a pleasure to appear at this special hearing of the House Energy Development and Applications Subcommittee to testify on the subject of "Future Coal Research and Development Needs". As the largest producer of coal in the United States, this is a topic of vital importance to Peabody. This year, our Company will mine close to 60 million tons of coal for sale to utility and industrial consumers throughout the United States. More than 70 percent of that total will come from midwestern mines located within a 250-mile radius of this site.

Definitions - Types of Research and Development (R&D)

I would like to begin my discussion by establishing a generic framework for discussing types of R&D. From there, I will move on to coal-related R&D, and finally, I will outline my views with regard to the role that should be played by the Federal Government.

For purposes of my presentation, the R&D effort can be conveniently categorized into three basic types:

- Basic Research - This is the first rung on the R&D ladder; the place where scientists delve into the basic nature of materials, chemical reactions, atmospheric physics and so on. The primary experimenters tend to be our universities and research labs.

- Exploratory Development - At this stage, the experimental work performed by the researchers is brought together for the first time to build a functional unit; a component, a module or a partial subsystem.

- Engineering Development - This phase involves the application of results achieved during exploratory development to a specific end use. It can include the development of a prototype piece of equipment or even a partial system to demonstrate feasibility and finalize design parameters prior to full production.

Areas of Coal-Related R&D

Given these broad definitions of generic types of R&D, the next step involves the identification of general areas where coal-related R&D should be taking place. Again, for my purposes, I have selected three:

- Coal Mining R&D - This area has to do with equipment and processes that improve our ability to remove the product from the earth through the use of either surface or underground mining techniques. It could involve the development of a new continuous haulage system for the former or improved earth-moving equipment for the latter application.

- Coal Utilization - This area can be subdivided into two parts: R&D that involves the direct combustion of coal to produce energy; and R&D that converts coal to an intermediate substance such as a chemical feedstock or a synthetic liquid that can then be used in place of petroleum-derived products to produce energy or other materials.

- Social Responsibility R&D - In some respects, this area is a subset of the first two. It involves the development of products and processes that are necessary to comply with health, safety and other environmental requirements established by the Federal Government in fulfilling its constitutional mandate to "promote the general welfare". It can take the form of a relatively small device that is attached to underground continuous mining equipment to reduce dust levels, to large multi-million dollar systems that remove sulfur dioxide emissions from the flue gas that is created when coal is burned in a large utility plant.

Role of the Federal Government

With these definitions in place, we can turn to the question of the Federal Government's role in coal-related research and development.

- Basic Research - A strong case can be made that the Federal Government should continue to take an active role in sponsoring basic research in all scientific disciplines. The very nature of this work generally makes its identification with a specific beneficiary impossible. The end result may serve no purpose other than to further man's understanding of the laws of nature; conversely, it could lead to breakthroughs in military, industrial or consumer-related fields that would benefit many.

- Coal Mining - It is difficult to conceive of any rationale for an active involvement by the Federal Government in coal mining R&D that has as its objective the improvement of productivity or the lowering of cost. This is a highly competitive industry with hundreds of equipment manufacturers and thousands of producers. Their ability to make the necessary technological advances is very evident when one looks at coal price movements until 1969 when regulations and inflation started to distort the picture. In 1948, the average price of a ton of coal produced in this country was $4.16. By 1969, it had increased to $4.99; only $.83 a ton -- well below the rate of inflation, which was nominal then by today's standards.

- Coal Utilization R&D - The situation here is slightly different than it is in the coal mining area -- not because there is a lack of competition. There is plenty despite the rhetoric that can be heard about the oil and gas industry, which probably has the greatest stake in advancing coal conversion technology. Rather, the difference turns on the sheer investment required to prove-out such technology and the fact that our national security is critically dependent upon an adequate supply of petroleum products, whether they be obtained from natural sources or synthesized. In this area, government involvement through exploratory development is clearly justified now, and expansion to engineering development could be warranted in the future depending on the pace of progress made by the private sector and the external risks to our current supplies.

- Social Responsibility R&D - This area is one where the Federal Government does have a role to play, particularly when the regulations imposed to advance the "general welfare" are beyond the state-of-the-art or entail expenditures that are far beyond the reasonable resource base of the impacted industries. The two areas that I mentioned earlier -- dust control and flue gas desulfurization -- are prime examples. In the case of the former, our Company was a partner with the Federal Government and others in developing a flooded-bed "scrubber" to reduce dust concentrations to levels considerably below those considered to be dangerous as far as pneumoconiosis ("black lung") is concerned.

Much still remains to be done in the latter area. Advanced sulfur dioxide removal devices, including fluidized bed combustion systems, must be developed if the major bituminous coal reserves of this country are not going to be precluded from solving our energy problems. Most of these reserves are also within that 250-mile radius that I mentioned earlier. In fact, Illinois -- our sister State across the River -- contains almost twice as many recoverable reserves than West Virginia, the State most American's think of when the subject of coal is discussed. There is very little question that the Federal Government has a major role to play in this regard. In fact, it is difficult to think of many other activities that better qualify as promoting "the general welfare".

Thank you for your attention. I look forward to answering your questions.

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biography

PEABODY COAL COMPANY

ROBERT T. WALLACE

Present Position:	Vice President-Corporate Planning, Peabody Coal Company, St. Louis, Mo., August 15, 1977-present.
Responsibilities:	Executive responsibility for corporate-wide long-range planning and related activities.
Past Positions:	Peabody Coal Company Consultant, St. Louis, Mo., July 20-August 15, 1977. Other Companies Vice President-Managing Director, Systems International Division, Computer Sciences Corporation, Falls Church, Va., March-July, 1977. Deputy Under Secretary, U.S. Department of Housing and Urban Development, Washington, D. C., 1974-77. Senior Management Associate, Executive Office of the President, Office of Management and Budget, Washington, D. C., 1973-74. Director, Commercial Systems Center, Computer Sciences Corporation, Piscataway, N.J., 1970-73. Manager, Program Development, Computer Sciences Corporation, Falls Church, Va., 1967-70. Manager, Long-Range Planning, Contract Administration, Missile and Surface Radar Division, RCA, Moorestown, N.J., 1957-67.
Education:	Harvard University, Graduate School of Business, Cambridge, Mass., Program for Management Development (PMD), 1961. University of Notre Dame, South Bend, Ind., B.S. in commerce, 1954.
Military Service:	U.S. Air Force, First Lieutenant, 1955-57.
Activities:	Member-American Mining Congress, Energy Policy Committee; National Coal Association, Economics Committee (1980); Chairman (1975-76), Procurement Committee, Interagency Task Force on Minority Business Enterprise.
Born:	August 13, 1932 New York, N.Y.
Immediate Family:	Mildred, wife; Jonathan, son, born January 17, 1961; Matthew, son, born February 16, 1962; Joseph, son, born October 1, 1963; Robert, son, born September 3, 1965.
Office Addresses:	Peabody Coal Company 301 N. Memorial Drive St. Louis, Mo. 63102 Phone: (314) 342-3400 Peabody Coal Company 1120 20th Street, N.W. Suite S-720 Washington, D. C. 20036 Phone: (202) 659-8101

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Mr. VOLKMER. Before we go to questions, I would like to have a little thing that might be unusual, we'll take about a 10-minute break before we go to the questions.

So we will recess until 11:30.

[Recess.]

Mr. VOLKMER. The subcommittee will come to order.

We will proceed now with the question period. I would first recognize Congressman Young.

Mr. YOUNG. I just have a few brief questions. I do appreciate Jim Sensenbrenner coming down here to be with us for these hearings in the St. Louis metropolitan area. Obviously the Illinois coal and water availability of this area is very important, I think, to the future utilization of coal.

I have a question for Mr. Wallace. I don't think you addressed that, but is Peabody operating the only coal slurry pipeline in the country right now, Mr. Wallace?

Mr. WALLACE. Mr. Young, we are not actually operating the pipeline. The pipeline is run by another company; but it serves a mine that we have in Arizona. It transports coal from the Black Mesa Mine which is located on the Hopi-Navajo Indian Reservation in Arizona to a powerplant just across the State line in Nevada, a distance of 273 miles. The system started operation in 1970 and I might add that it has run extremely well since that point in time.

One of the issues that certainly is pertinent, considering the current debate on slurry pipelines, is the use of water. I might point out that that part of Arizona, like most parts of the State, happens to be a very arid area. There is, however, a large aquifer underneath the Mesa, and we—Peabody—put wells down into the aquifer. We use something on the order of 3,000 acre-feet a year. This mine will run for approximately 40 years; and in that period of time, we estimate that we will use only 1 percent of the total quantity of water in that aquifer right now.

There is a caveat to that. The caveat is that we have been told by consultants, and I think also by some of the Government analysts who have looked at this, that within 18 months to 2 years after the depletion of our coal reserves, that aquifer will be back to where it is right now. So we will not even really use the 1 percent in the true sense of the word.

Mr. YOUNG. Have you looked at the controversial pipeline that is slowly wending its way through the Congress? We are not quite sure. That is called the ETSI.

Mr. WALLACE. That is the name of the consortium that would operate the first new pipeline, probably, that will come on line after the enactment of the legislation. Incidentally, I might point out that the lead member of that consortium is also the contractor that built the Black Mesa Pipeline I described.

Mr. YOUNG. I see.

Mr. WALLACE. All of the specifications for the Black Mesa Pipeline, I think almost without exception, that were set back in the late 1960's have essentially been met. I think we know how to build these lines safely right now. It is not an advanced technology issue per se, although there are certainly enhancements from the way it was done back when the Black Mesa Pipeline was built.

The answer to your question, Mr. Young, is that we have looked at it as a user. Although most of Peabody's 60 million tons a year are produced within a 250-mile radius of this particular location, we do have reserves in the West. In fact, we are a joint venture partner in a mine that will become operational in Wyoming that could make use of that pipeline. We are, from a user point of view, very much in support of that project. I think you will find the entire coal industry is supportive not only of the ETSI pipeline, but pipelines in general.

I do not have any detailed knowledge of the various issues on that particular pipeline, but it seems to me that they are not dissimilar to those faced at Black Mesa. In fact, the environmental issues are probably less troublesome than the situation that we faced in Arizona, because there we were dealing with a much more arid environment.

Mr. YOUNG. What river does that come out of, do you know?

Mr. WALLACE. It is an underground aquifer. Lake Powell is the closest major body of surface water. I might mention to this committee that we would be delighted to make arrangements for you to see that pipeline in operation if you would like.

Mr. YOUNG. Where does the water empty into?

Mr. WALLACE. The water empties into settling ponds and is eventually cleaned up and used by the powerplant. It is just on the other side of the State line in Nevada.

It seems to me, based on my limited knowledge of the ETSI pipeline that the water situation there, is less troublesome. If my memory serves me correctly, I think the Oahe Reservoir has something on the order of 126 million acre-feet of water. Our aquifer in Arizona has about 10 million acre feet. I said that we would use 1 percent and then it would eventually replenish itself. My recollection of the ETSI water situation is that it would use something like 0.02 of 1 percent. So it seems to me from a water point of view—and I realize we are dealing with an emotional, difficult, and sensitive issue—that ETSI probably has much less to be concerned about.

Mr. YOUNG. I appreciate your comments. As you know, it is very controversial.

Mr. WALLACE. I know it is.

Mr. YOUNG. Thank you very much, Harold.

Mr. VOLKMER. That is quite all right. We recognize the gentleman from Wisconsin, Mr. Sensenbrenner.

Mr. SENSENBRENNER. My question is primarily directed at Dr. Peterson. I would like to have the thoughts of the other witnesses on this subejct as well.

Dr. Peterson, in your testimony you talked about the "march-in" clause and its effect on putting a damper on research and development in this particular area. I think my colleagues would agree that the march-in clause was originally enacted as a way of preventing the private sector of the economy from, in effect, dumping all of their R&D costs on the Federal Government and then just benefiting from taxpayer-financed R&D to make a profit.

If the march-in clause were repealed by the Congress, do you think that would be the effect or do you think that would stimulate more private sector R&D funds in this particular area?

Dr. **Petersen**. I feel that there are two parallel issues that both have to be addressed simultaneously. I think solving one by itself does not really create the new environment that we are looking for.

The march-in area certainly is the thorny subject with respect to patent rights. What we are talking about is strictly the background patent rights that a company developed as a result of their own private funding over many years. Whether or not the government should have a right to "march-in" and get access to those rights at some future date. I think if that were addressed as was recommended to a Senate Committee on Science and Technology a year ago by the appropriate committee of the American Bar Association, I think the patent area would be substantially improved. I certainly recognize it has been improved from where it stood 2 or 3 years ago where the position of ERDA and early on the DOE was all the technology rights had to be titled to the Federal Government. So that has been, I think, improved significantly.

I do think in talking to my colleagues that are concerned about intellectual property titling and accesss to it that the technology data rights clauses are at this point in time a more formidable barrier than the march-in rights, so I think that would have to be addressed as well. What we are talking about here is a similar situation, except it is broader and encompasses all background technology that could be applied. The example given to me frequently is a company that had great expertise, say, in electrical machinery, if they were to apply an insulation that they had developed in a component for the Federal Government, there is the question of whether or not that background insulation technology would then have to be made available to other competitors, even though there are no patents involved in that particular subject.

Mr. **Sensenbrenner**. Do you see much of a conflict between U.S. patent law and international treaties relating to patents that were originally issued in other countries and are coming in here?

The reason I ask this question is I read in the New York Times on the way down here that there will be a U.N. conference on this subject next year. I am wondering whether our Government in union with private industries should be having some kind of a shopping list of changes that would be put on the table at that U.N. conference?

Dr. **Petersen**. I would be happy to have the head of our patent law department assist me in answering this question to you in a letter. I generally feel from what I have seen that the European nations at least where I have had a little more experience are much closer to the pattern that most of the private sector firms would recommend for the United States in encouraging not only titling of technology to the private sector, but exclusive use to the private sector and, of course, the Government both State and Federal Government, does enjoy significantly in the commercial success, of course, via the tax structure. We are only talking of patents that have a life of 17 years. As we see in our coal gasification effort, we started work in 1971. The earliest we can bring a plant on line is 1987. You are getting to a very significant part of the 17 years that relate to the early patents in the field.

Mr. **Sensenbrenner**. That brings me back to the first question I asked. That is if we make these changes, do you think the total amount of R&D funds, meaning government plus private sector funds, will increase, decrease, or remain the same? I am very fearful there might be a shift of funds by private industry away from what they are doing now by themselves into having the government pick up the tab, and we might end up having less R&D after the changes.

Dr. **Petersen**. I can't see them decreasing. I would think they would increase. I think along with their increasing, I think they would be more fruitfully employed and that there would be a greater incentive for firms that have the best know-how in a paricular area to work on the projects of greatest importance; but I think it would open, in the private sector, other avenues for more rapid commercialization of technology that would encourage the private sector to get to a point where they could institute cooperative programs.

I very much supported some of the discussion of other members of the panel in a feasilibility type of demonstration. I think that is a very appropriate role for cooperative funding with the Federal Government.

Mr. **Sensenbrenner**. Thank you, Mr. Chairman.

Mr. **Volkmer**. Thank you, Mr. Sensenbrenner.

Mr. Fuller, I will presume something in my question. If you disagree with it, you may say so.

Why has the coal-oil mixture program not really been accepted and utilized by commercial interests so far?

Mr. **Fuller**. I think there are a couple of reasons for that. First and foremost is that the utilization data on what happens when you burn a coal-oil mixture over extended periods of time in various combustion units, is just not available in the marketplace. I think the second reason is due to the economy at the present time from two standpoints. Number one, we are in a recession; capital dollars for conversion are tight, plus we are in an oil glut, and the basic economics of coal slurry fuels has to do with the spread between coal and oil. Right now we are seeing a reduction in that spread.

If we believe that oil is going to remain down in the foreseeable future, then I think you will see a depressed market; for COM. But in the event that we see the spread increasing between coal and oil, I think you will see the need for COM increase and we will move forward faster.

Mr. **Volkmer**. In other words, there we have a system that does not need a lot of continuation of further R&D; is that correct?

Mr. **Fuller**. That is correct.

Mr. **Volkmer**. And the knowledge is there; it is just the utilization of that knowledge?

That is right.

Mr. Naslund, you spoke about utilization of a task force in order to determine some priorities in utilizing commercial interests, university, government together. How would you overcome—I am going to presume another fact in my statement, but I think it is an accurate fact.

How would you overcome the natural reluctance to discuss issues which some company representative may have which may give away their competitive advantage in trying to obtain a consensus in determining what should be priorities? Would the people representing industry be able to be out in the open completely on determining priorities?

Mr. NASLUND. I think, Mr. Chairman, there are a couple of issues here. The first is a consensus of any kind, obviously, is the most difficult political process we have. It seems to me, though, that the proper focus for that discussion is prior to getting into a government agency where you have funds available. I am certain that many companies are reluctant to discuss proprietary or confidential information. We have been dealing in some of our work in synthetic fuels with several of the companies which are the stingiest in that area.

I think we have to focus on what are the technical issues involved. What I highlighted are the specific areas. I think even in looking at total technologies, there are specific areas that are crucial to reserve and solve the problems that industry and government and the private sector can agree upon.

Ultimately, having some small portion of a technology that is commercialized in a broad sense, as Dr. Weinhold pointed out, is much, much better than having basically no technologies in the marketplace at all. I think this is a decision private companies are going to have to make; that in order to achieve these consensus, they are going to have to give up a proportion of that.

I think the real nub of the problem I identified, and which I think Dr. Peterson has more completely identified, is the confidential information problem. In the Synthetic Fuels Corp., for example, you still have a question as to whether or not confidential information is adequately protected there, even though we have received assurances from the Synthetic Fuels Corp. that it would be protected. There is really no mechanism for distinguishing between public accountability of that organization and what must be kept confidential.

The Synthetic Fuels Corp., it seems to me, represents a form of this. Those issues are being discussed there. I think that is a prototype for the kind of discussion that ought to go on between all three of those groups.

I am not sure I answered your question. I guess for me the concern is that you get that discussion going much further ahead of time than when it gets into the government situation.

Mr. VOLKMER. Well, you feel then, from your answer to the question, that there probably would be some withholding unless there was some assurance that any proprietary information or confidential information that may be disclosed in discussions would not be made public; is that correct?

Mr. NASLUND. I think that is correct; yes.

Mr. VOLKMER. Do you also feel that there should be more of an interchange in order to get more qualified people within the government to operate the program to make the decision as to oversight, et cetera, that these should come from industry basically, if I remember your testimony? How do we get around this concern many of us in the Congress and in the public have about the revolving door policy of the people that are operating or benefiting from the program who are actually then operating the program? How do we get around that or away from it?

Mr. NASLUND. Probably the easiest way again is to have an overall program. I think you are not going to avoid the situation of having people coming through the revolving door any more than you are in other industries in which the Federal Government is very active, including defense and some of the other major program activities. I think the way to do that is simply to assure that a program has a long life, a plan, and a comprehensive participation by all the elements. I think that is the only way to assure that you will have people coming and staying because there is a reason to stay, not just to accumulate some experience and move on to a more lucrative situation.

Mr. VOLKMER. Dr. Peterson, when will the East Alton gasification project be completed?

Dr. PETERSEN. The plant is presently at the 50 percent point on construction. Subsystem commissioning will be done in parallel to the completion of construction. We plan to complete all commissioning by May of next year. So certainly this time next year we will be making gas fueling the boiler at the site.

Mr. VOLKMER. After that period of time, let's say you operated it for some period of time, 6 months to a year, do you feel there should be any significant risk or cost issue relative to subsequent installations? Do you think it would be pretty safe for anybody to do the same thing?

Dr. PETERSEN. First of all, this is a demonstration facility which is not justifying all of its cost strictly to the long-term commercial use there. In fact, we do not think the present mode of operating that rather antiquated boiler is a long-term utilization of this coal gasification facility. We see it as a test bed which would go on for 7 to 10 years to test other extensions of the technology and a combustion turbine demonstration is the next phase presently planned.

What we are doing presently is working with interest electric utilities on feasibility studies of specific plants at specific sites and specific coals. We presently have three of those underway and anticipate several more by this time next year. We will then go forward with the engineering with interested parties in parallel to the initial operation of the plant and our plan is to have sufficient engineering detail as well as confirmation of that engineering by plant operation so that we could commit to a plant in 1984.

We think that that commitment could be very similar in commercial integrity to a new coal plant with new gas desulfurization once we have that amount of operating experience.

We have two applications. One is the replacement of oil which I highlighted this morning. The other is to fuel a new powerplant. We see the application to the new powerplant as reasonably straightforward. The utility would own the gasification equipment just as it would own the rest of the powerplant. That is pretty straightforward.

In contrast, we see most of the oil replacement projects going with a third party ownership of the gasification facility, selling the gas over the fence to the electric utilities; and in that area, we are concerned with respect to the type of take-or-pay contracts that would be set up and how those contracts would be viewed by the State Public Utility Commissions or—if there are multiple States involved—the Federal Energy Regulatory Commission; and that the details of that contractual position allow suitable incentives for the stockholders of the company to take the risks that would be involved in the take-or-pay contract.

Mr. VOLKMER. As of this point in time, do you see any competitive advantage for the kilngas process over other options in providing this alternative fuel for electrical generation?

Dr. PETERSEN. Yes, we certainly do. I would like to answer your question in terms of saying that we see low Btu gas, which we are one of two or three that could be considered, as generically a fuel that deserves very significant attention for the next decade, because it has the least expensive processing requirement from the raw coal to a clean gas really of any of the coal synthetics. As a result, it can work on a smaller spread between the coal and oil price that Mr. Fuller was referring to than others. That enables it to be competitive early.

The other side of the coin is that because it is a lower heating value, nominally one-sixth that of natural gas, it cannot be transported large distances. You have to find instances where you can generate the gas within several miles of the using facility. But there literally are hundreds of opportunities to do that around the country that would make a very significant impact in our energy picture.

Mr. VOLKMER. Along that line, since we are talking about maybe scattering them around, what size kilngas unit would you say are practical?

Dr. PETERSEN. We are talking about 5,000 tons per day per unit as being a size we would be very comfortable with. In terms of mechanical componentry, that is smaller in size than the units we have used to process other large quantities of bulk solid materials, such as iron ore. So I think that would be a good size to work with. It is compatible with the 400- to 500-megawatt size electric utility powerplant which is essentially the common denominator of plants that have been built in the last 15 years and are now on the drawing boards.

Mr. VOLKMER. Could you also utilize this type of gasification unit for peaking purposes for powerplants?

Dr. PETERSEN. Technically you could, sir.

Mr. VOLKMER. Economically?

Dr. PETERSEN. The best utilization is a situation where you would have a duty cycle in excess of 40 to 50 percent because, of course, then you have the lowest capital contribution to the fuel cost product. Although the plant has the ability to follow very effectively—and, in fact, for new plants we are talking about combined cycle powerplants—that is a gas turbine and steam turbine together that utilize the product, and in that application, you can go up and down better and maintain part load performance better than with a conventional powerplant.

However, if you want to consider peaking only, which is frequently characterized as a few hundred to 1,000 hours a year, you would certainly be better off using a premium fuel in that facility which today is oil or natural gas and in the future would be methanol from coal; but at a price today of $100 a barrel equivalent—which is not economically attractive—you are better off concentrating on those cases where you have duty cycles of 50 percent or greater and can in fact produce a product substantially below today's price of oil.

Mr. **Volkmer**. Mr. Weinhold, you have described some of the projects within TVA that have benefited from an energy research and also from Government funding combinations with TVA, et cetera.

What Government programs would you say have been most beneficial to the activities you have shown in R&D?

Mr. **Weinhold**. In terms of appropriated funds, most have gone to the scrubber work which has been pretty nearly finished. The funds came initially through EPA beginning in the early seventies. That work has produced results which TVA and EPA have gotten out to a lot of people.

The other major area in which appropriations contributed was in the fluidized bed boiler development. TVA received appropriationed funds which went with funds from the TVA power system to build the pilot plant in Paducah. It is the combination of these funds plus EPRI funds that will operate the test facility.

Some of the funds, as I mentioned—the fluidized bed particularly—came directly to TVA, not through EPA or DOE. Funds passed through the EPA have been successful with the scrubbers.

Mr. **Volkmer**. You have suggested in your testimony that the Government provides leadership as far as research and development in the future. How would we do that? In other words, where is that leadership going to come from?

Mr. **Weinhold**. What I was trying to say is you need leadership to pull programs off, make programs go.

Mr. **Volkmer**. No question about that. Where does that come from? Is that within DOE? Where is it?

Mr. **Weinhold**. I think, practically, you have to find it in the private sector. Within the country, generally natural leaders are emerging. The whole Washington cycle in which the DOE operates does not encourage strong leaders to emerge to run programs. During most of our time when I was in DOE and its predecessors, my associates and I worried about justifying our existence and programs on a day-to-day basis. It is difficult to be out there leading, providing technological and business leadership under such conditions.

I think the key role of DOE and similar Federal funding agencies would be to identify good programs, good initiatives being developed in the private sector and to try to see that the funds and incentives come to them rather than trying to generate the leaders inside.

Mr. **Volkmer**. In other words, let the leadership come from the outside and not within the Government?

Mr. **Weinhold**. Yes.

Mr. **Volkmer**. Who identifies that then? Do you understand my problem?

Dr. Petersen, maybe you would like to speak to that? How would you identify it? I tried to identify it. I am not that expert.

Dr. **Petersen**. I personally felt the environment of the cooperative agreement that the Department of Energy utilized as a potential funding mechanism for jointly shared projects before the Synthetic Fuels Corp. was enacted offered a forum for the Federal Government to have various private sector teams come before them and present various projects and a mechanism for evaluating those projects to pick the ones that have the most attractive characteristics.

In our discussion with the DOE at that time, I was, however, upset and amazed to find that feasibility demonstrations would not fit their cooperative agreement model.

So we did not pursue that any further. Nevertheless I think that the Cooperative Agreement does offer a vehicle for dialogue between the private sector and the Federal Government. I think the concept of putting a leadership team together involving both the Federal Government and the private sector and in some cases I am sure the State government as well is desirable. I think the partnership could be developed if there was integrity amongst all parties and you could count on a long-term relationship where none of the parties had unilateral ability to change the picture.

Mr. **Volkmer**. Mr. Naslund.

Mr. **Naslund**. One of the focuses that might assist that process would be to center on some form of commercial rating; if you will, a Good Housekeeping seal on particular technologies. What I propose in that kind of scenario is that industry, and Government would be called in to basically rate certain of these technologies which would again give you a basis for the discussion.

If you had, for instance, some form of scientific court which could basically view the evidence, if you will, of the particular technologies from several sets of criteria, evaluate that technology, identifying the likelihood of that technology being put into the commercial marketplace, identifying particular groups of project teams and/or individuals and basically giving that kind of seal of approval, I think—as well as then providing the right kind of information to both the public and private sector, you might have the movement of discussion focused on the right kind of basis.

Mr. **Volkmer**. What you are trying to tell me is something that is similar to what you find—and I just mentioned it to the gentleman from Wisconsin—in the National Institutes of Health, the National Cancer Institute, et cetera, on those grants programs, peer review. This is basically what you are saying; use the people knowledgeable in the field to review the projects to determine whether or not they are viable and whether or not they are basically—whether or not there should be Government involvement leading to commercial aspects?

Mr. **Naslund**. I think that is right.

Mr. **Volkmer**. That delays everything, of course.

Mr. **Naslund**. I understand that delays things. Again, if you delay them in the beginning session before you spend a lot of the money, it seems to me you are a lot further along later on when you want to implement those programs and get them actually moving.

The other thought I had was the Federal Government does have a number of programs whereby interns are put into the private sector for various areas.

I think this type of exchange program might be very suitable in this area.

Mr. VOLKMER. You have no further questions?

Mr. YOUNG. I have two very brief questions.

I would like to ask Mr. Fuller, what does coal liquid do in that area? Who do you service?

Then what was your comment as it related to—did I get Florida in part of your testimony as it related to the inland waterway system?

Mr. YOUNG. What is your service area at this particular time? What about the inland waterway system you mentioned?

Mr. FULLER. As contained in my statement, Mr. Young, Coaliquid has been in business for about 6 years. We are a coal slurry fuel processor. We have a technology of a coal-oil mixtures which is currently available in the marketplace.

We have ongoing programs in R&D and coal beneficiation plus coal-water slurries.

My reference to Florida was in regard to the transportation system. I feel that moving coal around is very important. I believe my reference was that it takes about $30 a ton to move coal from eastern Kentucky to central Florida, and I recommended that the Congress support the extension of the inland waterway system such as the Tenn-Tom program and coal slurry pipelines to bring about competitive ways to move coal around in a more cost effective manner.

Mr. YOUNG. Just one question I guess maybe to Mr. Weinhold.

What is the natural gas usage at TVA? Is that pretty important? If anybody else on the panel would like to address it, too, I am thinking about the decontrol of natural gas in 1985, particularly—I am sure this will have some effect on the TVA situation.

Mr. WEINHOLD. TVA's basic sources of energy for electric generation are: hydro, about 20 percent; coal, which has traditionally been the big chunk; and nuclear, which is coming on very strongly now. We have five nuclear units operating.

We utilize oil and natural gas in peaking turbines for winter peaks, tens or hundreds of hours a year. We are in the process of trying to provide the flexibility to use either natural gas or No. 2 oil for these turbines, whichever is the cheapest.

I think right now we use less than one percent, of our total energy in the form of oil or natural gas.

So, TVA is fortunate in not needing to use a large amount of this premium fuel. I wouldn't expect TVA's power operations to be affected significantly by the natural gas pricing system.

Mr. YOUNG. A minimum?

Mr. WEINHOLD. Right.

Mr. YOUNG. Any other members of the panel want to comment on the natural gas price increase we will have in 1985?

Mr. WALLACE. I cannot resist.

Mr. VOLKMER. What will coal be in relation to it?

Mr. WALLACE. Coal will be, as it historically always has been, priced at the margin because it is a highly competitive fuel. We would like to see natural gas become a highly competitive fuel, too.

I don't know what the price of natural gas should be or would be. I do not think anybody knows. We do not know how many wells have been shut in just waiting for decontrol to take place. We do know that decontrol is a—kind of a misnomer, because your old gas will still be controlled after 1985. Some of that will run into the 1990's.

It seems to me that the Congress has moved from a highly regulatory role in energy to one that relies more on the market. With regard to natural gas, a major regulatory constraint was lifted by the Congress when it repealed the requirement that natural gas could not be used for electric power generation after 1990.

The only trouble is they didn't go and change the other part. They changed the utilization part but not the pricing part.

So we still have a price controlled fossil fuel competing not only with coal but with oil as well. We think that that creates inefficiencies, and we would expect to see these disappear just as they did when oil was decontrolled.

We would expect to see that happen if natural gas were decontrolled.

Many utilities that are strapped because of capital formation requirements and poor financial conditions in general just simply will not come off natural gas. It is much easier, as Mr. Simon pointed out, to pass that cost through; and in many cases—I think over 40 States have fuel adjustment clauses—it is on automatic recapture.

The areas involved Mr. Young, are, as you know, in the southwest. Its much easier to continue to burn gas than take your chances on a rate increase by building a new, highly capital intensive project .

So we strongly advocate the decontrol—the true decontrol—of natural gas.

Dr. PETERSEN. I might just indicate that the heavy consumption of oil by electric utilities, basically is on the east coast and down through Florida, and to some extent in the gulf coast. Natural gas is heavier in the south and in the west.

I think the exciting area where a lot of change can develop is the gulf coast area. Transportation from the midwest is good, through the Mississippi River system. There needs to be improvement over toward Florida, as Mr. Fuller indicated.

But I think coal can effectively compete via coal gasification in those areas. There are quite a few large plants on waterways in that area that are now natural gas or oil. Most of the utility planners and other energy planners that I talked to forecast that long-term natural gas contracts would equate with heavy oil contracts by the end of this decade if decontrol takes place.

Mr. VOLKMER. Mr. Fuller.

Mr. FULLER. Mr. Chairman, I would like to add a comment on the decontrol of natural gas. I firmly support the decontrol of natural gas.

There was a school of thought that said we did not really have an oil crisis, we had a drilling crisis because of regulation. We deregulated oil and we all saw what happened.

We might have the same type of thing with natural gas. In order to find the true economic best fuel for any particular area, we must have them on an equal footing. We have coal and oil unregulated. I think we need true unregulated natural gas.

Mr. VOLKMER. Well, I don't want to get into a big discussion on this. It is time for lunch.

I would say my largest reservation in regard to immediate decontrol is, again, the question of price and what will happen to the economy in general with that type of impact. I don't know.

I guess it depends upon whose projections you look at as to what would happen. In other words, if there was decontrol, what would the price be this winter? Some people have said you will see a 50-percent price increase. Other people have said because you add much more gas to the thing, you may see a decrease.

I don't know who you want to believe; but personally, I feel that the process that is being followed is probably the most valid, and that is the gradual decontrol, not worrying about that impact.

I would worry if we did have a large impact in a time of recession such as the one we are in now. What would happen to the economy? Those are my personal feelings. Many people would not be able to afford that cost increase. We will have to wait and see what happens by 1985, I guess.

Mr. YOUNG. Maybe we won't be around to worry about it.

Mr. VOLKMER. That is true. That is my concern, the economic impact of it. Even though we did see more oil drilling, that seems to have faded away. We do not see a lot more oil produced in this country right now. We don't see the decline anymore. We had about a 3-percent decline. We don't have that decline. But we are not seeing a lot more oil produced in this country than before.

I don't know if we will see this in gas.

Mr. WALLACE. Domestic oil production up about 2 percent, as I recall, from last year. There is a change in the trend, anyway.

Mr. VOLKMER. We are not going to be energy-independent in oil because of deregulation. I don't think anybody can make that statement.

We need to get on with some of these other things so we can become energy-independent in the future.

I will adjourn the hearing for now. We will recess until 2 o'clock, at which time Mr. Young will assume the chair.

Mr. YOUNG. Gentlemen, thank you very much. I appreciate your presentations this morning.

[Whereupon, at 12:20 p.m., the subcommittee recessed, to reconvene at 2 p.m., the same day.]

AFTERNOON SESSION

Mr. YOUNG [presiding]. We will start the second part of our hearing on coal research and development. It is designed to draw on the experience of organizations which have been leaders in coal research activities.

We are looking for the lessons that can be drawn from past successes so that they may guide us in our future plans.

Coal has been a major economic factor in the development of this region. We would like to be confident that coal will be available to meet future energy needs. Due to the high sulfur content of most of the coal in this region and our concern over air pollution, it is necessary to insure that our use of coal is efficient and environmentally sound. It is a challenge to our technology .

We are looking forward to the witnesses providing us a factual basis for some of our future plans.

It is with pleasure that I welcome the members of our second panel: Dr. Dan L. Hartley of Sandia National Laboratories; John S. Mead of the Illinois Energy Resources Commission, and Dr. Larry J. Shannon of Midwest Research Institute.

We will be welcoming Dr. Bernard S. Lee of the Institute of Gas Technology in a little while.

Mr. Sensenbrenner will be trying to make an airplane very shortly. Having said that, I think we will start with Dr. Hartley.

Jim, when you feel you have to leave, we can stop.

STATEMENTS OF DR. DAN L. HARTLEY, DIRECTOR, COMBUSTION SCIENCES, SANDIA NATIONAL LABORATORIES, LIVERMORE, CALIF.; JOHN S. MEAD, DIRECTOR, ILLINOIS ENERGY RESOURCES COMMISSION, SPRINGFIELD ILL.; AND DR. LARRY J. SHANNON, EXECUTIVE DIRECTOR, ENGINEERING AND APPLIED SCIENCES GROUP, MIDWEST RESEARCH INSTITUTE, KANSAS CITY, MO.

Dr. HARTLEY. Thank you for inviting me here. I would like to submit my entire testimony for the record. I will summarize parts of it, if I may.

I would like to express my perspective to this meeting as Director of Sandia's and DOE's National Combustion Research Facility. It is a fairly unique facility in Livermore, Calif.

I will be making my observations on coal research primarily as they relate to combustion science and the reverse.

I always find it interesting to state—and I have several times in the past—that although combustion is responsible for over 90 percent of the energy in this whole country, very little has been done to understand the fundamental combustion process at all in the past, particularly in the United States, and it is especially true for coal. Although coal science represents and epitomizes the challenge for new ways of studying combustion problems, very little is yet being done.

I would like to highlight what I think are some of the reasons for that and hopefully give some suggestions as to what might be done in the future.

Our facility is only one of many around the country that have taken advantage of advanced techniques in the last several years, which has resulted in a significant improvement in the ability of researchers and scientists not only in the National Laboratories, but in industry and universities as well, to do things they haven't done before.

As a bit of background, I would like to state—and I think everybody agrees—that coal utilization is going to be increased significantly in the next 20 to 30 years.

I would like to quote a report that I read just 2 weeks ago from a congressional Joint Economic Committee that stated they foresaw a boom in coal in the United States that would result in, as they call it, a catalyst for American reindustrialization. I hope that is true.

They also go on to report that there should be sufficient demand for coal by the year 2000 that the United States will be exporting on the order of 350 million tons of coal. That is in line with the MIT world coal study.

If that is true, that will result in a $17 billion plus in balance of payments for the United States.

I think that should be considered as a very important reason to be pushing science in support of coal utilization.

That committee also concluded that in order to accomplish this, the United States should increase the coal R&D program to the 1981 DOE level which was on the order of $1 billion.

They also emphasize in order to accomplish it, new combustion equipment and emission control concepts will be needed to improve the environmental acceptability and productivity of those machines.

As I see it, the principal means of increased coal utilization in the United States in the next 20 years is most probable through direct burning of pulverized coal both in utilities and in large industrial boilers.

The new technologies for fluidized bed combusters and slurried fuels and other liquids from coal are even going to further encourage coal utilization in the next 20 or 30 years.

We heard testimony to that effect this morning, although it is slow to start. I am sure 20 years from now we will see quite a bit of it around. So what does combustion research have to do with all of this? Let me say from my view, many of the primary limitations to the design and success of a coal utilization system are combustion related.

I will just highlight three things: Environmental acceptability of coal systems is traceable to flame-generated gaseous species, particularly nitrogen and sulfur oxides, and to solid effluents of soot and ash. These are generated in the combustion process and can be controlled in the combustion process.

Second is fuel tolerance, or the ability to burn a wide range of coals. We have seen this becoming a more and more important problem in the utilities as they run out of the particular coal their utility boiler was designed for and they have to switch to another type of coal.

The problems associated with doing that substitution are combustion related and can be controlled by proper modifications of the combustion process.

Third is fouling and corrosion which is a very serious limiting problem. This is a result of chemical effects from sulfur, halogens, and alkaline metals in the coal.

Those, too, can be influenced by additives or other means of controlling the combustion process.

Just to put this in somewhat more of a perspective, I would like to discuss the lifetime of an individual coal particle from the time it enters the boiler, which is shown on my first chart. A typical pulverized coal particle is normally 70 microns in diameter, which is about the size of face powder. There are two proceses that happen. One is very fast and is shown by the red part. That is where the volatile gases come off the coal; they ignite and burn with a lot of gas phase chemistry. This is where the nitric oxides and sulfur oxides are born. It takes a few milliseconds to a tenth of a second.

There is another set of processes that are very slow, taking on the order of a couple of seconds. During that time the char burns out, and the ash is released from the coal and melts and fuses, which can clog and corrode the system. The two seconds it takes for char to burn out is one reason boilers are so big, a couple feet high, to get the residence time to make that char burn up.

That is a schematic. To give you an idea of the various processes, my second chart is an actual picture of pulverized coal particles burning. The lower region, the black region above the blue line, is the region it takes for a particle of coal to burn up before it ignites. The streaks on top are the result of char burnout later in the lifetime of the coal particle. Very little of this is understood in any detail at all.

Finally, if you look inside this boiler or this flame at one of those particles, and my third chart shows one, a 70-micron particle taken with a high speed, highly magnified photographic system using laser illumination, you see the particle, a cloud of gases around it condensing to form smaller soot-like particles and later forming a sort of liquid tail in the aft region of the particle.

This is information that was not known even a year ago. This is new information about the physical processes involved in the combustion of pulverized coal particles. This is the kind of information that scientists need in order to predict what goes on in a boiler in a real design problem.

I would like to say a great deal has been done in the last couple of years largely the result of a program within fossil energy that I refer to as the AR&TD program. Perhaps you know it as the advanced research and technology development program.

It is a new program within fossil; new in that it is only a couple years old. It has borne a lot of fruit in these new scientific understandings.

I would like to say a few words about the Federal role as I see it, why the Government should be supporting this sort of research rather than industry. Part of it, of course, deals with the worldwide environmental issues of acid rain and upper atmospheric CO_2 which are related to the combustion of coal. Another part of it deals with the strategic use of coal internationally and how we might eventually end up having a very serious influence ourselves on the world energy supply. Those are Federal issues.

Finally, I would like to say the required fundamental information I referred to is generic to an extremely broad set of combustion equipment, not just utility boilers but industrial heaters, steam raisers, process systems that are being converted to coal or designed to use coal. That is a broad industry that does not have its own R&D. It is a broad industry that needs a central resource to draw upon. I think that is where the Government has something to contribute.

There is a new emphasis as well that the Government can put in the program right now. For the last 15 years, the Federal Government has been involved in combustion research and support of energy systems. Early it was the EPA, but EPA's emphasis was on stack gas cleanup. There was very little emphasis on what was going on inside the combustion system.

In the early days of DOE in the 1970's, the effort was on coal extraction. There was some effort on cleanup, but not very much. There was a great deal of effort on conversion, but, again, very little on combustion .

The standard phrase was "we already know how to burn coal" the trouble is nobody would recognize seriously we don't know how to burn it cleanly, efficiently, and reliably.

I would like to say that things have changed. As I mentioned before, the AR&TD program got under way a few years ago. That put new emphasis on coal combustion research. It needs to grow. It needs to involve universities, national laboratories, the energy technology centers, and industry. It does to date, but it is a fairly modest program.

Some of the currently considered advanced concepts for coal combustion, such as fluidized beds, will depend even more strongly on this new type of information to design them to meet the standards that are going to be required. There is a very serious problem right now in that the current fossil energy program, and their budget projections for fiscal year 1983 virtually eliminate the AR&TD effort, yet there are entire teams around this country that are quite motivated and are contributing new information that I am afraid will be cast aside. They will undoubtedly be difficult to reassemble in case we have another energy emergency in the country.

In my view, we are fortunate we have gotten something started. I would like to see it continue.

A question that was asked in the letter of August 4 that came to us was to discuss models that exist within the Government for comparable programs.

I have an experience with a similar activity and I would like to share it as one that I advocate. It is exemplified by the engine combustion technology project within DOE conservation. This has been an ongoing effort for about 8 years, involving national laboratories, universities, private companies, and our domestic auto manufacturers. That team effort has had a significant influence already on our domestic automobile engine design research staff, and they will attest to that fact.

The success of that whole program has been that it has lasted for a significant period of time. It has involved a broad set of contributors working on a team effort. I think that is the same sort of activity that should be organized for coal research. The AR&TD effort is attempting to go to do a similar activity. If they succeed, I think the country will benefit enormously.

I certainly emphasize combustion science as one subset of coal research. It is just that, a single subset. There are other areas that have similar problems, although I believe combustion is pivotal to the success of any new technology in burning coal, even to the expanded use of our conventional technologies for burning new coals as they come on the market.

As far as recommendations, let me say that there are existing documents and testimony from leading scientists around the country, and they have adequately described a very extensive broad list of research topics. I would like to single out only a few.

I have referenced some of the documents in my testimony. I would emphasize the following three basic elements:

First, bench scale and midscale experimental studies of the mechanisms and rates of chemical and physical and aerodynamic processes which are critical to pulverized coal combustion and conversion, with specific emphasis on the fate of mineral matter and on organic bound sulfur and nitrogen.

Second, on the development of computational models incorporating the best information available on the many chemical and physical processes affecting combustion. I emphasize that topic because this country is in a leading position in the ability to use computers to develop and apply predictive models for design purposes.

The third area is the development and application of improved diagnostic methods capable of probing harsh particulate-laid environments for developing the information needed to validate and develop the engineering models as well as to evaluate the overall system performance.

As a step in that direction, I endorse the AR&TD project. Another theme I hoped I developed in my testimony is to emphasize that the time has come for the coal industry to enter the era of high technology. I believe the national laboratories in this country are a primary source of interdisciplinary teams around which exist the most sophisticated high technology tools. They should be asked to participate and be drawn upon to contribute to the coal research program.

The combustion research facility that I direct is only one small example to illustrate that point. I do believe it is a good one.

Earlier testimony to this committee has recommended returning the proposed fiscal year 1983 funding for AR&TD to the 1982 level. I do not believe that is enough at all. This country's coal research effort overall should be more reflective of the congressional Joint Economic Committee's report I referenced earlier where they recommended a severalfold increase for AR&TD. It should lead the list.

[The prepared statement of Dr. Hartley follows:]

ENERGY DEVELOPMENT AND APPLICATION

Dan L. Hartley

Director Combustion Sciences

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Livermore, California

Future Coal Research Needs

Chairman Fuqua and Distinguished Committee Members, thank you for inviting me to present my views on coal research needs. I will use this opportunity to express my serious personal concerns about the fate of research on coal utilization and coal science in the United States, particularly as it relates to coal combustion.

My concerns reflect my perspective as Director of DOE's national Combustion Research Facility at Sandia National Laboratories in Livermore, California. My involvement there has proven to me, and to many distinguished members of the industrial and academic community, that research has made, and can continue to make, a significant contribution to solving this country's energy problems.

Ninety percent of our energy comes from the combustion process, and both pollutant formation and system efficiency are intimatly related to that process. It should be no surprise that combustion science in this country has undergone a major revitalization in the last few years as our policy makers have, albeit belatedly, come to recognize its importance. Our facility represents one small part of that revitalization. More importantly, we represent a commitment to introduce new research methods (diagnostics and computers) into a field previously stymied by lack of tools.

Coal research epitomizes the challenge to apply these new tools to overcome the serious limitations to increased coal utilization. Coal is a dirty, nasty, inconsistent fuel, and it burns in a highly polluting, corroding, and unreliable manner. These problems have to be solved. This is not a matter of choice but of absolute necessity. Applying research at the front end is without question the most effective and the most economical approach. I believe an approach which joins the research forces of national labs, universities, industry and the energy technology centers--all of whom have highly complemental capabilities--can solve most of the limiting technical problems in coal combustion. The Advanced Research and Technology Development (AR & TD) project of the DOE Office of Fossil Energy has started such an effort, but my concern obviously, is that the current Administration's budget will not permit a viable program for AR & TD. A well-managed, long-range research effort is absolutely essential if science is to make its indispensable input to the coal utilization problem.

We face the same international competition for technology development in coal utilization equipment that we do in engine design. Our country simply cannot afford to stand aside as our competitors continue to erode our one-time leadership in science and technology, and coal science is no exception.

The new scientific capabilities in computers and diagnostic systems, such as we have at the Combustion Research Facility and those at many research centers around the country should be drawn upon now to introduce these advanced capabilities into the supporting technologies for coal research. Because of developments in the last eight years, we are in a unique position, internationally, to make a great stride forward for the U.S. in coal research with advanced research methods, but only if we get started now. This will be the thrust of my testimony.

Background

The extensive coal reserves of the United States (around 5000 quadrillon Btu's, or quads) constitute nearly 90% of our entire energy reserves. The direct use of coal, however, accounts for less than 20% of energy consumed in the U.S. This apparent imbalance in reserves and direct use of coal is a well-documented result of the more desirable aspects of, and the current investment in, equipment requiring premium fuels (natural gas and petroleum). I believe we can all agree, however, that political, economic and population pressures will force increased direct use of coal and a continuation (probably an acceleration) of fuel substitution where coal or coal-derived fuels will displace premium fuels. My point is not to present new projections, but to point out that any reasonable projection places severe environmental, efficiency, safety and reliability demands on equipment manufacturers and designers--demands that cannot be met without an understanding of the fundamental characteristics of coal combustion and their relation to coal properties. Policy makers and technologists in other countries are already responding to these demands, primarily I presume, because they don't have the luxury of our abundance in coal supply--a luxury I fear will lure us into complacent acceptance of technology advances from abroad rather than developing them here in the U.S. This could have the same devastating effect on our boiler manufacturers that it has had on our auto industry.

Reports to our own policymakers are beginning to quantify this point, as stated in a recent congressional Joint Economic Committee report: World demand for energy by the year 2000 will be met by significant expansion of the U.S. coal industry--perhaps doubling its production by 1990 and tripling it by the year 2000. They report that this boom in coal demand may "catalyze an American reindustrialization." It would also markedly improve the U.S. balance of payments. If exports reach 350 million tons by the year 2000, in line with the MIT World Coal Study, coal exports could add $17 billion to the positive side of the U.S. trade ledger.

The Committee report concludes that to accomplish this goal the U.S. should increase the coal R & D program to the 1981 DOE level--$1 billion. Also, the government should stress improvement in technology and machinery used in mining and burning coal. They emphasize that new combustion equipment and emission control concepts will be needed for improving both productivity and compliance with environmental standards.

The principal means of increasing coal utilization for the U.S. in the foreseeable future is most probably through direct burning of pulverized coal in utility and large industrial boilers. In addition, pulverized coal substitution in other systems may displace premium fuel by as much as 15 quads in the utility sector and 12 quads in the large industry boiler sector by the year 2000 (roughly one-third of the estimated transportation requirement). New technologies for fluidized bed combustors, slurried fuels, and liquids from coal may even further encourage coal utilization.

How does combustion research contribute to this hoped-for scenario? The primary limitations to the design and success of a coal utilization system are all combustion-related:

(1) environmental acceptability--traceable to flame-generated gaseous species (nitrogen and sulfur oxides) and solid effluents (soot and ash).

(2) fuel tolerance, or the ability to burn a wide range of coals--traceable to alterations in combustion control allowing such substitution, (flame stablization, recirculation time, ash characteristics).

(3) fouling and corrosion--a result of chemical effects from sulfur, halogens and alkali metals found in coal.

To put these problems into a more graphic perspective, let us envision a hypothetical life-cycle of a pulverized coal particle from the time it enters a combustion system until it dies to ash in the exhaust. On the microscale of an individual coal particle, typically 70 microns diameter (the size of face powder), the combustion process can be visualized as a sequence of rapid heat and mass transfer processes (poorly understood) coupled with heterogeneous (gas-solid) and homogeneous (gas-gas) chemical reactions (even less understood). Figure 1 shows these processes schematically, and figures 2 and 3 illustrate the actual combustion process at the microscopic level.

In a global sense, coal combustion can be described as a rapid devolatilization process (one-tenth second) followed by slow char burn-up (up to 2 seconds). This slow phase dictates the relatively large size of coal burning equipment (a utility boiler may be 200 feet high.).

Qualitative data to date indicate that overall rates, extents of reaction, detailed mechanisms of oxidation of carbon and hydrogen, and conversion of fuel-bound sulfur, nitrogen and mineral matter to gaseous and solid species are strong functions of the principal properties of the coal particles (size, porosity, moisture content, elemental chemical composition) and the surrounding environment.

All these fundamental details about individual coal particle combustion must be known to adequately predict burner behavior, which in turn must be sufficiently well described to predict overall furnace performance. Such intimate dependance on details holds even more strongly for many of the advanced concepts for coal utilization.

Don't we already know how to burn coal? Certainly we do, and have for centuries, but we do not yet know how to burn it cleanly, safely and efficiently. There is no acceptable model of the chemical structure of coal and there are no predictive models of the chemical and physical behavior of coal during combustion.

Until recently no federal or industrial program existed at all in this country to develop such a predictive design capability. It's not surprising then that we find ourselves lagging behind other countries in coal technology. Only in the last few years have researchers from industry, universities, national labs and energy technology centers begun to work together on these problems; and they have made noteworthy progress. The research information that is needed has been well-described in existing documents, new measurement methods and computer systems are available in this country's research centers, and the goals are achievable.

Federal Role

The required fundamental information alluded to above is generic to an extremely broad set of combustion equipment, from industrial heaters and steam raisers to utility boilers. It is my firm conviction that the infrastructure does not exist within that broad industry to conduct such research--certainly not with any degree of coordination or freedom of access. A centrally funded program involving industry, national labs, energy technology centers and universities is required; only the federal government has the capability of undertaking a long-term R & D task of this magnitude. Further, the national labs are a committed arm of the government through exclusive contractual arrangements and their attention to these efforts requires government support.

Also, the primary limitation to the future use of coal is the very serious problem of environmental acceptability, and the resulting necessity for federal and state governments to regulate performance standards. This is not a mere legal barrier to coal use, but a very real technological problem which has far-reaching environmental consequences--so far reaching as to embroil nation against nation with concerns about acid rain and upper atmosphere CO_2 build-up resulting from the combustion of fossil fuels. The environmental performance of a coal system is, of course, intimately controlled by the combustion process. Federal support for technology needed to meet these government regulations is particularly appropriate.

The Federal program should focus on technologies that can be implemented in the combustion process rather than the traditional approach of stack clean-up. During the late 1960's and into the 1970's, for example, the U.S. Environmental Protection Agency established some R & D programs to support environmental issues. Their efforts almost exclusively focused on post-combustion clean-up. It became assumed within EPA and DOE (ERDA) that DOE had responsibility for combustion analysis--yet little was done. During the late 1970's the EPA did sponsor a modest fundamental combustion program but it was short-lived and did not embrace a bold scientific thrust, nor did it draw upon a broad team of contributors.

The R & D efforts that emerged in DOE (ERDA) in the 1970's were focused on extraction and conversion, with coal utilization being addressed through expensive demonstration projects rather than through longer-range research--an influence of its predecessor, the Office of Coal Research. It has taken far too long for our energy planners to recognize the need to provide the sound technical basis required for improved coal utilization.

Finally, the strategic use of, and international allocation of, coal resources is a matter of federal concern. Because of our enormous national coal reserve, the U.S. has a clear responsibility to lead in support of technologies which allow environmentally acceptable use of coal. The development of capabilities to burn broad classes of coals, and thus allow a more flexible distribution of coal resources among our domestic users as well as our foreign allies, is clearly in the general interest of the United States.

Appropriate R & D

After decades of virtually total lack of attention, this country has succeeded in putting into motion a well-planned and broadly based program of research in coal combustion and conversion (sponsored by the Advanced Research and Technology Development (AR&TD) Project within Fossil Energy/DOE). While this has been a belated development, it is one that appears to be universally welcomed by both the technologists and researchers in industry, and by the universities and government. And ironically--and sadly typical these days--this only happened after nearly ten years of spending billions of our dollars on demonstration plants that have gone nowhere--largely because of the absence of the very fundamental information we are now trying to generate. The currently considered advanced concepts for coal combustion such as fluidized bed combustors and multiple-staged pulverized coal combustors show promise for low-pollution and efficient heat generation, but that promise will be slow to materialize without supporting research, and even newer technologies may never be realized without the sometimes fortuitous spinoff that comes from fundamental understanding.

As has been eloquently pointed out by this hearing's other witnesses, we are all aware of the national endorsement for expediting development of the capability to substitute coal and coal-derived fuels for the premium fuels--petroleum and natural gas--in conventional and advanced power systems. The endorsement stems from the obvious favorable strategic and economic consequences of this course of action. With this view in mind, many knowledgeable observers regard the historical weakness of the U.S. coal research program, compared with corresponding efforts elsewhere--for example, in Western Europe, the Soviet bloc countries, and Australia--as an alarming deficiency.

Now, just as the embryonic U.S. coal research effort is about to enter its infancy--and will require all the attention and commitment a promising youngster deserves--we find it situated precariously near an abyss, into which it may well disappear because of massive cuts in the DOE Fossil Energy Research Program. Research on coal combustion, coal conversion, and coal science is about to be severely truncated. There is apparently no fallback position. Furthermore, given the present climate in Washington, there appears to be neither money, mandate nor inclination at DOE/Energy Research, NSF, or DOD to pick up the pieces. These pieces include research teams, adept in using the most advanced research methods, equipped with the most sophisticated experimental and computational devices, and situated throughout this country in industry, the universities, the national laboratories, and the energy technology centers. As their support and funding disappear, they will of necessity be disassembled and dispersed; they most certainly will not remain intact and ready to respond to the next declaration of emergency occasioned by the next oil embargo--prepared to reconstitute on short notice a viable national coal research effort.

In my view, we are fortunate that this nation has finally begun to acquire potential for genuine breakthroughs in understanding the behavior of coal in combustion and conversion environments. It is precisely because we have been able to dedicate many of our best people in the engineering and physical sciences to a vigorous effort and to equip them with the very best analytical tools, that coal research in the United States has at last started to gain the respect of the U.S. technical community and has come to be viewed as something much more than a black art. Let's keep the momentum going.

A Model for Comparable Research

There are existing programs that can be used as a model for the government's program in coal research. In my experience I have seen three types of programs, each with different approaches and objectives. One is the NSF approach of providing funding to a diverse and poorly connected community of scientists with the goal of creating research opportunities, primarily for universities. This approach is useful for generating graduate students, but does not deliver an integrated program dedicated to solving important problems. The second approach is the other extreme, where the industry sponsored programs, by economic necessity, focus only on immediate problems. The third approach, the one I advocate, is exemplified by the Engine Combustion Technology Project within DOE Conservation. There, teams of national labs, universities and industry concentrate on "classes" of combustion design in engines (e.g. diesel, stratified charge, etc.) with each contributing its specialty. Meeting as teams (not assorted contractors) twice a year for several years, these groups have made significant impact on the domestic auto industry. This project has achieved international recognition with all foreign auto manufacturing countries judiciously studying our teams. I recommend such an approach for coal research.

Recommendations

I have chosen to emphasize the role of combustion science in the coal research program because I believe it is pivotal to successful, increased coal utilization. Coal science in general, however, is in the same state as the existing program in combustion--it is in dire need of strong federal support.

The payoff for this country far exceeds the investment: the reported potential of $17 billion per year in balance of payments for the U.S. export market and the unmeasureable value of U.S. reindustrialization certainly justify a program at the billion dollar level for coal research. But much more effort than that in the past should be devoted to solving the more fundamental problems in coal combustion and coal conversion.

The existing testimony and recommendations by our leading scientists and technologists have adequately described the important research areas (for example in the APS Study Group on research planning for coal utilization and synthetic fuel production, and the Sandia Report on Pulverized Fuel Combustion Technology). The recommendations of these studies are broad, but I would emphasize the following specific research elements:

(1) Bench scale and mid-scale experimental studies of the mechanisms and rates of chemical, physical and aerodynamic processes critical to pulverized coal combustion and conversion, with specific emphasis on the fate of mineral matter and organic-bound sulfur and nitrogen.

(2) Development of computational models incorporating the best information available on the many physical and chemical subprocesses affecting coal combustion. These models must be aimed at interpreting and scaling experimental results.

(3) Development and application of improved diagnostic methods capable of probing harsh, particulate-laden combustion environments to extract the information needed to develop, and validate, the engineering models and to monitor overall system performance.

As a step in this direction, a responsive research plan for integrating the technical forces of this country has been born in the AR & TD project.

Another theme I hope I developed in my testimony is to emphasize that the time has come for the coal utilization industry to be welcomed to the world of high technology. I believe the national laboratories in this country are our primary source of large interdisciplinary teams, armed with the most advanced high-technology tools. The special resources of those laboratories should be brought to bear, aggressively, on the important coal research problems, while involving the general research community where their specialities contribute. The Combustion Research Facility is an example to illustrate this point, and a resource to embrace.

Earlier testimony to this committee has recommended returning the proposed FY 83 funding for AR & TD to the FY82 level; that's not enough. This country's coal research effort overall should be more reflective of the congressional Joint Economic Committee recommendations (several-fold increase) and AR & TD should lead the list.

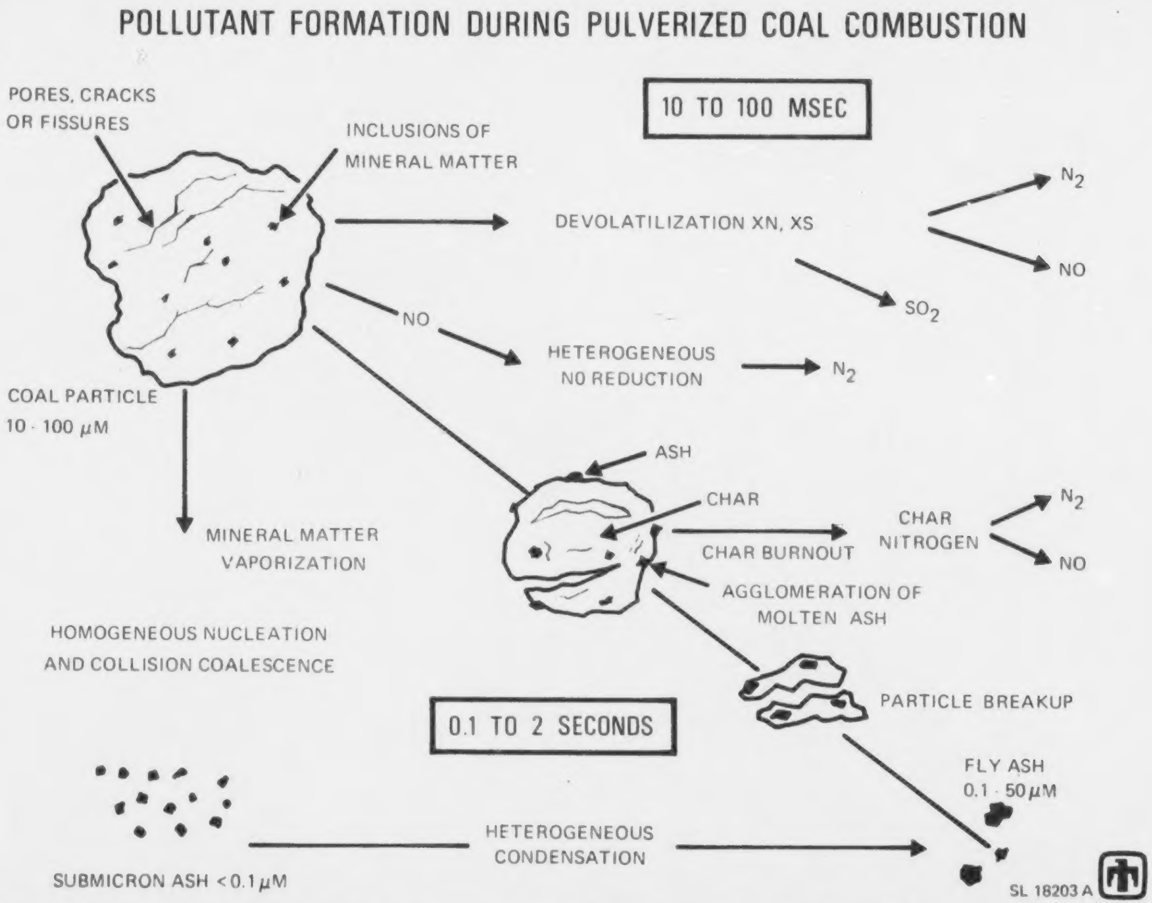
POLLUTANT FORMATION DURING PULVERIZED COAL COMBUSTION
10 TO 100 MSEC
PORES, CRACKS OR FISSURES
INCLUSIONS OF MINERAL MATTER
DEVOLATILIZATION XN, XS
N2
NO
SO2
NO
HETEROGENEOUS NO REDUCTION
N2
COAL PARTICLE 10 - 100 μM
ASH
CHAR
CHAR BURNOUT
CHAR NITROGEN
N2
NO
MINERAL MATTER VAPORIZATION
AGGLOMERATION OF MOLTEN ASH
HOMOGENEOUS NUCLEATION AND COLLISION COALESCENCE
PARTICLE BREAKUP
0.1 TO 2 SECONDS
FLY ASH 0.1 - 50 μM
HETEROGENEOUS CONDENSATION
SUBMICRON ASH <0.1 μM
SL 18203 A

Figure 1: Schematic of Mechanisms of Combustion of a Single Pulverized Coal Particle

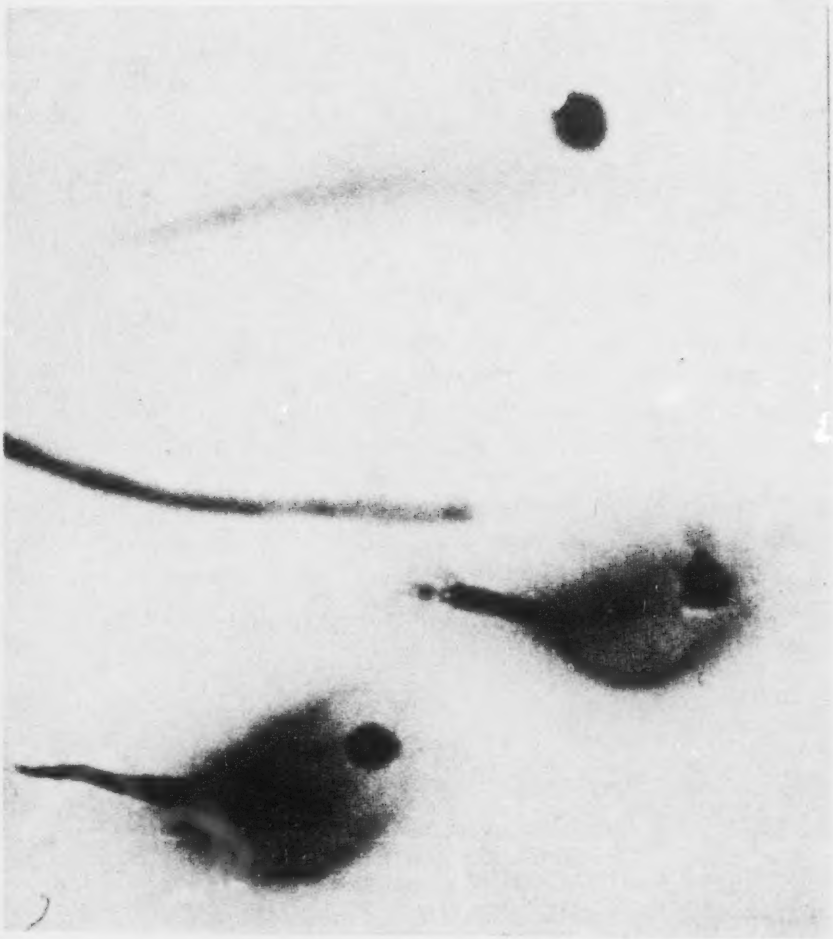

Figure 2: High-Speed Photo of Coal Particles During Early Stages of Combustion

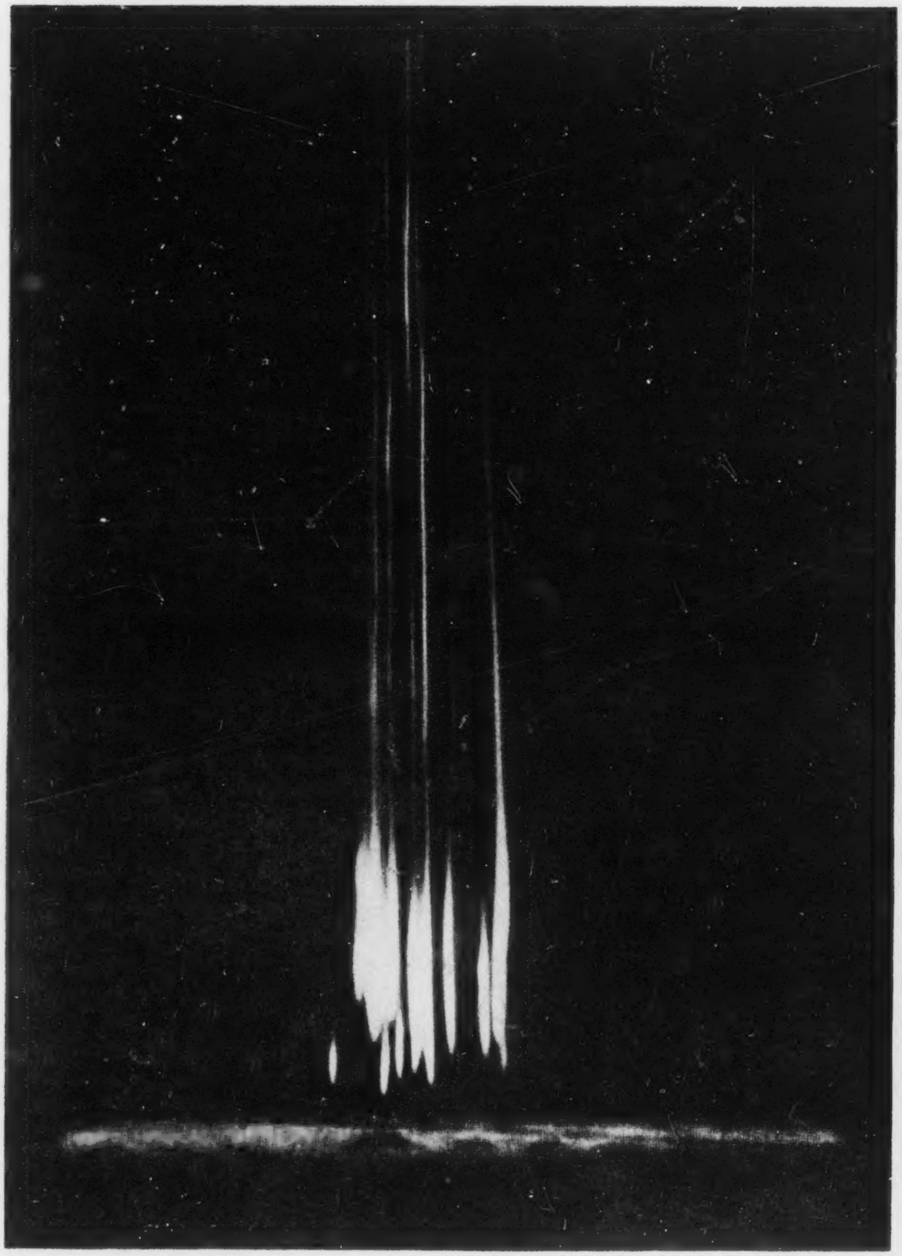

Figure 3: Emission from Pulverized Coal Burning in a Lean Methane-Air Flame

Dr. Dan Hartley

Dr. Dan Hartley is the Director of Combustion Sciences at Sandia National Laboratories in Livermore, California. He graduated from the Georgia Institute of Technology in 1967 with a Ph.D. in Aerospace Engineering, and was a Research Fellow at the Von Karman Institute in Brussels, Belgium before joining Sandia in 1968.

As a research staff member he was a pioneer in the development and application of laser-based diagnostics to the study of turbulent fluid mechanic processes. In 1974 he led an APS-sponsored summer project at Princeton University entitled "The Role of Physics in Combustion," which coincided with his initiation of the combustion research program at Sandia. He conceived the National Combustion Research Facility, a $10M scientific complex dedicated to advanced methods in combustion science, of which he is now Director. He has led or contributed to numerous studies dealing the application of advanced methods, experimental and analytical, to problems in energy research.

Dr. Hartley manages two departments comprising six research divisions, totaling 70 scientific staff, dealing with fundamentals of flames, engine combustion and coal combustion. The research also includes the development and use of advanced laser diagnostics and computational techniques.

Dr. Hartley is also the U.S. technical representative to the Combustion Research Group of the International Energy Agency, and was responsible for initiating the group in 1978. He also serves on several Review Committees for Lawrence Berkeley Laboratories, Lawrence Livermore National Laboratories, and NASA. He is currently a member of the Board of Directors of the Combustion Institute.

Mr. YOUNG. Thank you, Dr. Hartley.

Mr. Sensenbrenner wants to ask some questions, I believe, at this time.

Mr. SENSENBRENNER. Thank you very much.

One of the other subcommittees of the Science and Techology Committee has held extensive hearings into the acid rain problem and what can be done to reduce acid precipitation and problems in places like the Adirondack Mountains of New York State as well as southern Ontario and southern Quebec. Do you foresee from your knowledge that there will be any breakthrough in combustion science as it relates to reduction in acid rain?

Dr. HARTLEY. Yes, sir, I do. Even the current concepts that we consider advanced but yet are on the market, like fluidized bed combusters, are capable of removing most of the sulfur. Something that does bother me—and I read a recent editorial in Science magazine just last week—there appears to be a great deal of money, manpower, and energy focusing on the study of chemical reactions that occur in the atmosphere that result in the acid rain rather than dealing with the chemical reactions that create it in the first place.

I think the emphasis is wrong there. More money should be spent and people involved in trying to solve sulfur removal in the combustion process itself.

Mr. SENSENBRENNER. As you know, the research budget for acid rain has been increased by 50 percent. That is one of the few budgets that have been increased in the last couple of years.

Do you know if any of the increase is being used for combustion research rather than research into the other kind of atmospheric reactions?

Dr. HARTLEY. I do not think it is. I think it is all atmospheric chemistry, but I am not sure.

Mr. SENSENBRENNER. I would appreciate our staff trying to find out the answer to that question. I do believe you make a very good point, Dr. Hartley. If we can somehow find out what causes sulfur and nitrogen emissions in the combustion process, and figure out a way to control them there, it will be far easier and far cheaper to do that than doing it on the atmospheric end.

Thank you, Mr. Chairman.

Mr. YOUNG. Thank you very much, Jim. We appreciate your attendance at the hearings today in St. Louis.

Mr. SENSENBRENNER. Thank you, Mr. Chairman.

Mr. YOUNG. Mr. John Mead.

Mr. MEAD. Just one comment on the acid rain issue while you are still here.

I believe that you are right. The research funding is going into atmospheric research. Indeed, the Federal legislation creating that study, the very language of it, is oriented toward atmospherics rather than combustion. As somebody from a high sulfur coal State, I can say I think the money will be much better spent over the long run if we concentrate on combustion science. We are prepared to move the technology that will burn our high sulfur coal, but we cannot do it alone.

Mr. SENSENBRENNER. I think what we are looking at from a congressional standpoint is figuring out how to use those research dollars in the most cost effective manner. The testimony that we have gotten at several hearings before the Subcommittee on Natural Resources, Agricultural Research, and the Environment is that there is no straight-line effect in reducing SO_2 and NO_x emissions and the acidity of the precipitation, or, put another way, if you have an area of lakes and some, because of the type of bed they have, become acid far quicker than others, we could have an SO_2- and NO_x-free precipitation in upstate New York and still not be able to save some lakes.

Given the imprecise nature of the atmospheric science, I think perhaps some redirection of the research and development funds would be necessary in order to provide the cost effectiveness that I think all of us want to see, whether it be Congressmen, whether it be people in this area such as yourself, or the general public that is becoming increasingly concerned about the acid rain problem and what to do about it.

Thank you.

Mr. YOUNG. Thank you.

Mr. MEAD. Forgive my interruption, Mr. Chairman.

I will continue my remarks. If they could be made part of the record, I would like to read excerpts from them.

Mr. YOUNG. Your full testimony will be entered in the record without objection.

Mr. **Mead.** I do not appear here today as a director of a research organization; rather, the Energy Resources Commission is an agency of the Illinois General Assembly. We have had some policy experience in helping Illinois institutions get more funding for basic coal research and we have been funding commercialization and demonstration projects for a number of years.

Since 1975, the State of Illinois has been a partner with both private industry and the Federal Government in a wide variety of coal utilization research, development, demonstration and commercialization projects. We have been active through a $65 million general obligation bond fund, from general revenue bonds, and from funds from public utility taxes to pay for all phases of coal research and development.

A few projects have gotten underway, many have not. We have been the victims of an attrition rate similar in the big synfuel projects as the other States. There is a little bitterness. I will not dwell on these points today. It is quite obvious everyone has the same axes to grind.

In spite of the failures, and in the face of present and future reductions in Federal support for fossil energy research and development, Illinois and several other major coal-producing and coal-consuming States have substantial opportunities for important coal development projects.

I would like to make a few points today to demonstrate that Illinois, Ohio, Kentucky, and, I think, the Western coal-producing States and the Eastern coal-producing States make good partners for Federal funding.

As the Federal budget goes down, the money that the States have to offer for basic research and for the more grandiose commercialization projects becomes a bigger share of the total pot. I think that is something Congress should look at closely because we are motivated to continue our research and development.

I have just a couple of words about the need for high-sulfur coal. I think most of our discussion today has generally focused on coal development and coal research, and not on differentiating between the high-sulfur and low-sulfur varieties. We feel in Illinois that the Illinois Basin high-sulfur coal is a major national resource that is desperately needed both from an energy security standpoint and from the standpoint of the economic importance to this region.

I think the fact that national policy mandated the Clean Air Act and may mandate strict acid deposition controls, is a strong reason for continued Federal support of high-sulfur coal projects. We are seeking to solve national problems, and all we ask is that we can continue to produce our resource, which for this part of the country is a very major resource.

I also have a few points about the past Federal support. Federal funds that have found their way to research and development for coal in Illinois have contributed to the development of excellent research institutions. I think it is safe to say that the Midwest is a center of excellence for coal science worldwide and that, in large part, Federal funds have helped to create that.

I think the State governments and the private industry can take a bigger share of the role of keeping those research laboratories strong, but a failure of future Federal support will certainly jeopardize many of these institutions.

I think in the past years there has been an unwillingness and inability of Federal decisionmakers to allow their partners, the States and research institutions, to exercise their own judgment in the development of programs and projects. The built-in inability of Federal research projects to give State regulators adequate flexibility has had a heavy impact in Illinois and I would say that is true of Kentucky and other Illinois Basin coal States.

A major disappointment in past years has been the handling of university coal research laboratories. There was a program which I think many of us in Illinois thought was a very good one from the start that would create regional university coal laboratories. That was under the Surface Mining Reclamation Act of 1977. The cooperation and work that went into those proposals was wasted in the end when the appropriations committees in Congress and the Department of Energy could not get together and really keep that project going.

I think the idea of very strong regional university research institutions is still a good one. The national laboratories certainly fill a major role in that, but I think that the State institutions, the University of Illinois, Southern Illinois University, University of Missouri, Northwestern, and others can, and are willing to contribute. I think perhaps other funding mechanisms and again a stronger State role may bring that to pass. It is something we still need.

In the demonstration and commercialization areas, as I have said, Illinois has been beaten around a little bit. We have some demonstration and commercialization projects underway today, and they are State funded with major private contributions. Kilngas is an excellent example.

The single federally funded coal demonstration project that existed in the State of Illinois was unfortunately shut down by a Federal agency. We at the State contributed money to that project. A private corporation, Combustion Engineering, contributed millions of dollars to this project. I am speaking of the fluidized bed combustion project at Great Lakes Training Station north of Chicago.

I think that the failure of the Federal Government to see that project through has really harmed the development effort in fluidized beds. Perhaps this was not going to be as successful as other fluidized bed programs, but it was one that had actually gotten off the ground, and it was in a testing phase. Unfortunately, that boiler stands idle today and it is sort of a bitter reminder to the State of Illinois that the Federal Government has not been a very good partner in past years.

I would like to turn to the impact of the current administration on coal research. In pruning the fossil energy R&D budget for fisal year 1982 and cutting it deeply in fiscal year 1983, the administration has placed many research institutions in a position from which they may not recover, even with subsequent increases in State and private support. State investments in university and other institutions will see little return on that investment for many years.

One of our real fears is that the crucial transition from major Federal funding to private support for research, especially for the later phases, is just not going to occur because the cutoff of Federal funds was so abrupt, so deep. The momentum is lost. I am afraid many of these institutions will be forgotten as major coal centers. That is something that we can ill afford to have occur.

There is a major thrust from the Midwest this year in fiscal year 1983. It has been led by Wilbur Dodge, the manager of environmental control at Caterpillar Tractor Co., who has formed a coalition to attempt to get $5 to $10 million for more precombustion chemical cleaning of coal. This is an area that the State of Illinois has made plans to contribute upwards of $1 million to support.

We hope that the Federal Government will join us in this effort. Bill Dodge has been to Washington. I think he has done a good job rallying people to look first of all at the sulfur problem and, second of all, at the precombustion clean-up alternative.

With all the cuts going on for fiscal year 1983, we hope that the area of precombustion will get, a separate line item and $10 million of funding.

Another positive development is the possibility—and I think it is a probability now—that the Carbondale Mining Techology Center will be leased to Southern Illinois University by the Department of Energy with some Federal funding for its operation. This has been conceived as a joint private university-Government coal research center. I think it is an opportunity for the State and private sector to get involved, to not only get some of our money going into it, but to get some of the institutions that are controlled by the State active and helping in the coal research effort.

I think that Government ultimately does its best job in basic research, but there is a gap there. Again, it is that transition to private risk that has to be filled, and I feel that the States can help. But Federal Government money is still needed, at least for the next several budget years, to fill in that gap.

I would like to discuss just briefly the role of Illinois and other high sulfur coal-producing States in the future of coal research and development, because I think these motivated and active States can play a major role.

A continuation of high sulfur coal research, development, and demonstration is a major energy priority for the State of Illinois. The State has developed a review and approval mechanism for the funding of basic coal research and large-scale demonstration projects.

This dedication of coal utilization is also reflected in the activities of Kentucky and Ohio. These States and other coal-producing and coal-consuming States could play a major role in achieving future national coal R&D objectives. The traditional regulatory and business development activities of these States, coupled with their support for their research institutions, greatly improve the effectiveness of the Federal Reserve dollars.

I think if States could receive a continuing amount of money from the Federal Government for their own research efforts, the extended leverage that Federal money can achieve is going to come about in three different ways. Let me just briefly cover those three.

The first, and I think the foremost for now, is that the regulation of public utilities is primarily a State concern. A coordinated State program with its regulatory agencies actively involved with interested utility companies and research institutions could move more advanced combustion and emission systems into the proving stages rapidly. This State-utility partnership, supported with some Federal contribution, may be especially important if new emission control levels are mandated by Congress.

The emission reductions mandated by the 1970 Clean Air Act amendments might have resulted in greater technological innovation and less coal-switching had States like Illinois been able to direct funds into emission control development ventures.

I think the ability of the State regulatory entity, the public utility commissions, to give the private utility company the go-ahead in some kind of coordinated program is a key.

Second, Illinois has a good track record in developing and operating its university research centers. I think with this record of sustaining these programs, some of which have been around for many years, is a major achievement. It has occurred in Illinois and in other coal-producing States. I think the States can continue that coordination only if a lot of the backtracking and backbiting at the Federal level can be eliminated. State mechanisms must be allowed to function more freely.

Finally, if the Federal Government is willing to take interested States on as partners in coal research and development, the resources of these States would be available to add to or follow up on the Federal contributions. In Illinois, general obligation bonds are now used to support coal development projects and revenues collected from public utilities have begun to go to basic research.

A willingness on the part of the Federal Government to contribute a portion of the project costs to these State-sponsored R&D projects would be an efficient and nonduplicative way to concentrate total research dollars. Such a partnership would also encourage a greater investment of severance and other energy taxes into coal and other energy research. I do not think this is something that is limited to the coal area.

Ultimately it could put some of this coal severance tax money, which has been so criticized from a national perspective, back into solving national needs.

In conclusion, I would just like to add that the coal-producing States are operating from a position of enlightened self-interest. I think that is something that the Federal Government should recognize and should encourage. We are not saying we can do it on our own.

Far from it, but I think the Federal Government can offer a nationally coordinated perspective to all of this.

The point that I would like to reemphasize is that there are some States that are ready to go. They have the money. They have the motivation. I urge you to take advantage of their abilities.

Thank you.

Mr. YOUNG. Thank you, Mr. Mead. We appreciate your testimony.

[The prepared statement of Mr. Mead follows:]

Statement of
Mr. John S. Mead
Director, Illinois Energy Resources Commission
Before The
Subcommittee on Energy Development Applications
of the
Committee on Science and Technology
United States House of Representatives
August 23, 1982

My name is John Mead and I am the Director of the Illinois Energy Resources Commission. I do not appear before this Subcommittee as the representative of an industrial or institutional research organization, rather the Commission is an agency of the Illinois General Assembly, and its Commissioners are legislators and private citizens. The Commission is an active participant in Illinois' efforts to protect and expand its coal industry. Our work has included the establishment and the funding of coal utilization projects in Illinois, as well as activities on the state and federal levels to improve the competitive position of Illinois coal resources and maintain a reliable source of energy for our economy.

Since 1975, the State of Illinois has been a partner with both private industry and the federal government in a wide variety of coal utilization research, development, demonstration and commercialization projects. A few projects have gotten underway, many have not. Through federal government indecision and timidity and often because of a lack of private capital or economic uncertainty many programs designed to help solve the problems of high sulfur coal in Illinois have never gotten off the ground.

In spite of the failures, and in the face of the present and future reductions in federal support for fossil energy research and development, Illinois and several other major coal producing and coal consuming states have substantial opportunities for important coal development projects.

In this congressional forum I would like to discuss the coal states' potential leadership role in future government sponsored coal research and development.

Why Midwestern High Sulfur Coal is an Energy Resource that Should be Supported.

National energy policy through four administrations has stressed the critical importance of coal as a resource that is both domestic and economically recoverable in large quantities. In response to rising petroleum and natural gas prices and increased demand for electric power, coal has increased its share of the national energy supply. This increase has been and continues to be in the form of low sulfur coal from eastern and western coal fields. In the traditional strong market areas of midwestern coal the increased use of western low sulfur coal has displaced the use of locally available coal.

The strong competitive advantage of low sulfur coal in the past decade is of course a consequence of federal and state air quality regulations under the Clean Air Act. Although changes made in the Clean Air Act in 1977 were designed to reduce its deleterious impact on high sulfur coal, it appears very unlikely that high sulfur coal will ever maintain a healthy share of the energy market without the extensive use of environmental controls. The coming decade holds the prospect of new emission standards for the control of long range pollution problems such as acid deposition. Even the compromise positions on the acid deposition control issues aim significant new standards directly at the midwestern high sulfur coal market region.

In response to the decline of high sulfur coal demand caused by environmental regulation and the failure of such a major coal resource to respond to the rising costs of other fossil fuels, the major high sulfur coal producing states and the federal government have established a variety of research, development, demonstration and commercial support programs. The action of the states may be characterized as enlightened self interest, but what about the federal government? Has it been a justifiable and essential involvement and can the nation afford to continue or even enhance the federal support of one region's coal resources? The answer to these concerns is a strong yes.

There are compelling factors of national scope that justify the need for federal support of high sulfur coal development.

- - There continues to exist a critical need to maximize the national energy production capability. In the next 20 years the U.S. can be a secure energy exporter with the advantages of substantial freedom from petroleum interruptions and even a positive energy trade balance if we can improve the range of applications and the environmental control methods for our largest reserves of coal - high sulfur coal.

- - The overexploitation of low sulfur western coal may result in serious environmental problems in western coal mining regions. The development of large surface mining in Wyoming and Montana has continued to be a controversial use of land and water. It is not unreasonable to expect that the ability of western mines to deliver ever increasing amounts of coal to a nationwide and export market may be impaired by future state or local actions to control the impact of mining operations. Such events may be impossible to counteract by a high sulfur coal industry that has been in an uninterrupted decline.

- - The coal industry in the midwest is an important economic base for a region that is undergoing fundamental economic change. The ability of the coal producing states of Illinois, Indiana, Ohio and Kentucky to increase the sale of coal can help to offset the declining economic strength of a region that has seen much of its manufacturing business exported to other regions or other countries. Locally available coal can also attract new industry if its use can be shown to be economical and environmentally acceptable.

- - Perhaps the most compelling reason for continuing strong federal support for high sulfur coal development is the fact that it has been national environmental issues and federal law that has been largely responsible for the decline of midwestern coal use in industrial and utility applications. Air quality controls are an essential part of our nation's future and increased controls may well be necessary. The continued support of high sulfur coal utilization R & D is a small cost to spread over the nation when it can result in achieving both environmental protection and an adequate energy supply. The dollar fairness and the cost effectiveness of such support is highlighted by the level of cooperation and commitment that has been demonstrated by the industries, institutions and governments of the high sulfur coal states.

Past Federal Support for High sulfur Coal Development: The Illinois Experience.

The federal funds and other support that has found its way to coal research and development in Illinois has, for the most part, contributed to the development of an excellent institutional research base. The regional and national benefits of the research institutions of the state will far exceed the federal contributions. The principal failure of federal support has been a consistant inability to follow through with even the most effective concepts and the unwillingness or inability of federal decision makers to allow their partners to exercise their own judgement in the development of programs and projects. The built-in inability of federal agencies to give research directors, project developers, or state regulators adequate flexibility has had a heavy impact in Illinois; especially in terms of the loss of non-federal funds that could have leveraged state and private contributions.

- - Basic Coal Support

Without federal dollars and other assistance institutions such as the Coal Extraction and Utilization Research Center at Southern Illinois University, the Illinois State Geological Survey, the Institute of Gas Technology and the states' schools and colleges of engineering and the Argonne National Laboratory would not be centers of excellence in coal research. These institutions together with other universities and research centers in Kentucky, Indiana, Ohio, Missouri and Iowa constitute a world center of coal science.

A major disappointment for basic coal research was Congress' and the Carter Administration's handling of the University Coal Laboratory concept under Title VIII of the Surface Mining and Reclamation Act of 1977. The cooperation and work that went into the laboratory proposals was wasted in an unreasonably complex and rigid review process which was ultimately abandoned by both the Department of Energy and the Appropriation Committees. The laboratory concept was and remains valid for the high sulfur coal region; its success depends on a commitment of the federal government to rely on the ideas and plans of the institutions and the involvement of interested states.

- - Demonstration and Commercialization Projects

Illinois is a burial ground of federally supported coal synthetics and advanced combustion projects. The promising innovative projects that are now under construction or in the planning stages are ones that have sought state not federal participation.

The list of projects that were abandoned after federal support was withdrawn includes: Commonwealth Edison's Powerton combined-cycle gasification system; a G.E. fluidized-bed demonstration; the Coalcon gasification system; Amoco's oil coal liquids refinery and a General Foods fluidized bed project. Most of these projects had received substantial private and state capital support. A recent event that has been particularly frustrating to the state was the decision by the Department of the Navy to suspend operations of a fluidized bed boiler which the Navy funded together with Combustion Engineering, the U.S. Department of Energy and the State of Illinois.

The failure of federal support for development and demonstration projects in other states has had an impact on Illinois' coal development objectives. Low and medium Btu gasification to meet the environmental needs of older coal and oil boilers or for new combustion turbine applications is a technology that could be meeting commercial needs in the near future. The failure to proceed with low and medium Btu gas turbine demonstrations has pushed the technology back behind the level of gasifier development. Similar delays have also occurred in the development of advanced flue gas desulfurization and fluidized bed combustion processes.

The Impact of Coal Research and Development Policy Changes Implemented or Recommended by the Reagan Administration.

The changing coal research and development program and budget under the present administration is founded on two major principles: federal involvement is most effective in long term, high risk research - the marketplace should govern later stages of development; and secondly, that the R & D budget must reflect fiscal restraint. These are principles that researchers and policy makers in business and government in the midwestern coal states by and large accept. The additional administration goal of improving regulatory policies that effect marketplace decisions may ultimately benefit high sulfur coal development. However, in the implementation of these principles there are policy decisions and uncontrolled factors that may have a very detrimental effect on high sulfur coal development.

- - Basic Coal Research

In pruning the fossil energy R & D budget for FY 82 and cutting it deeply in the FY 83 budget the Administration has placed many research institutions in a position from which they may not recover even with subsequent increases in state and private support. State investments in university or other institutional research will see little return in the coming years. Midwestern universities will recieve less benefit through the use of the national laboratories such as Argonne and Ames, at a time when these laboratories are moving ahead with the use of dry flue gas desulfurization for high sulfur coal and other advanced flue gas desulfurization and precombustion control processes.

These and other combustion, emission control technology and coal preparation research areas are crucial for the high sulfur coal industry, yet the DOE budget could only fund $15.1 million for all of these direct coal utilization research objectives. Wilbur Dodge, Manager of Environmental Control at Caterpillar Tractor Company, has led a coalition of government agencies, coal users, coal producers and research institutions from the midwest. This group, which includes the Energy Resources Commission, has worked to increase the federal budget support for sulfur emission control research; especially advanced precombustion treatment. Hopefully, the work has added an additional $5 million for a high sulfur coal program.

The elimination of funding under the university coal research category is a further erosion of the high level of coal research that has been achieved in the past decade in the midwest. The abrupt cut-off of funds may reduce the effectiveness of state coal research funding in Illinois and will make the transition of basic generic research to applied, industry supported work more difficult and less frequent.

A positive development for university research is the possibility that the Carbondale Mining Technology Center will be leased to Southern Illinois University by DOE with significant federal funding for its operation as a joint private/University/government coal research center.

- - Demonstration and Commercialization Projects

The policy of limiting DOE support to the early or "proof of concept" stages is difficult to fairly apply to high sulfur coal utilization. Many potential industrial investors in unproven coal utilization technology are unwilling to take on a project alone because of inexperience in dealing with the innovative process. The jump from proof of concept to a market has widened in recent years.

Electric utilities are the largest users of high sulfur coal. The introduction of advanced direct combustion, emission control systems or low - medium Btu gasification into their systems in the high sulfur coal market region would mean continued and expanded coal use within the restrictions of the Clean Air Act or possible acid deposition control. Because of state utility regulation the funds that a utility may expend on research and development, or the commitment to unproven technologies is limited. In electric utility applications the federal involvement should be pushed far beyond the basic research level.

The loan guarantees and price supports offered by the Synthetic Fuels Corporation make the picture for some high sulfur coal projects hopeful; however, it is unfortunate that innovative incentives for the much more common direct combustion facilities do not exist.

The Role of Illinois and Other High Sulfur Coal Producing States in Future Coal Research and Development.

The continuation of high sulfur coal research, development, and demonstration is a major energy priority for the State of Illinois. The state has developed review and approval mechanisms for the funding of both basic coal research and large scale demonstration/commercialization projects. This dedication to coal utilization is also reflected in the activities of Kentucky and Ohio. These states and other coal producing or coal consuming states should play a major role achieving future national coal R & D objectives. The traditional regulatory and business development activities of the states coupled with their support of their research institutions can greatly improve the effectiveness of federal research dollars.

If a state could receive a general grant of coal development funds, the decision making at the state level would increase the effectiveness of the funds in three ways.

- - The regulation of public utilities is primarily a state concern and it is the regulated nature of electric utilities that has been a major barrier to the participation of these major coal users in the research and demonstration of innovative coal technologies. A coordinated state program with its regulatory agencies, interested utility companies and research institutions, could move advanced combustion and emission control systems into the proving stages very rapidly. This state-utility partnership supported with some federal contribution may be especially important if new emmision control levels are mandated by Congress. The emission reductions mandated by the 1970 Clean Air Act Amendments might have resulted in greater technological innovation and less coal switching had states like Illinois been able to direct funds into emission control development ventures.

- - Illinois has had a good track record in developing and operating its universities, scientific surveys and other research centers. These institutions achieved a high level of cooperation with business sponsors and other groups participating in research. With the failure of the University Coal Laboratory idea and the elimination of most of the Regional Energy Technology Centers, the maintenance of strong state research institutions as centers of excellence in coal science should be a priority. Illinois and other coal producing states have and will continue to support these resources but their maintenance will become more difficult as less federal funds are earmarked for university research.

A federal policy of providing a reliable source of support to state research institutions (like the state agricultural research station support program) would provide a base from which greater private participation can grow. The keys are: a more stable source of funding - which together the state and federal governments must supply; and committed research centers - which a number of coal producing states have already developed with prior federal support.

- - If the federal government is willing to take interested states on as partners in coal research and development the resources of these states would be available to add to or follow up the federal contribution. In Illinois, general obligation bonds are now used to support coal development projects and revenues collected from public utilities have begun to go to basic research. A willingness on the part of the federal government to contribute a portion of the project costs of state sponsored R & D would be an efficient and non-duplicative way to concentrate total research dollars. Such a partnership would also encourage a greater investment of severance and other energy taxes into areas that will improve our energy supply and utilization systems. This would ultimately reduce the negative impact that the severance taxes have on energy consuming states.

A greater reliance of state initiatives in high sulfur coal research and development can create a steady and improving technology development mechanism that has been lacking in the national energy picture. I have great confidence in the power of enlightened self interest and in the ability of individual states to promote private participation in projects from the research stage up to commercial demonstration.

Summary

High sulfur coal is a resource that needs and deserves federal support at both a basic scientific research level and at the demonstration/ commercialization stage of utilization technologies. Past federal activities laid a foundation for a high level of research excellence in high sulfur coal, but little transfer to commercial applications has been effectively supported. Present federal policy is leading to a significant reduction in the research capabilities in high sulfur coal, a trend which may be best mitigated by a greater reliance on successful state programs and decision making.

I appreciate this opportunity to share this Illinois perspective with the Subcommittee and the other members of the Panel.

Mr. YOUNG. I would like to welcome Dr. Bernard Lee, president of the Institute of Gas Technology.

Dr. Lee, you were not late; we were early. Mr. Sensenbrenner wanted to get back to Wisconsin. He asked us to move ahead a little bit on the panel so he got a chance to hear some of the testimony this afternoon.

He has left to catch the airplane to Milwaukee.

It is my pleasure to introduce to the panel, to the members of the staff, Dr. Lee. Your testimony will be entered in the record. You may summarize in whatever way you would like. We appreciate your being with us today.

Dr. LEE. I apologize for being late. I have been trying to get here since 10 this morning.

I represent the Institute of Gas Technology, an organization specializing in energy R&D for over 40 years. I was asked to discuss some of the philosophical views of national energy policy, because I think once you set the right philosophy we can take action as a Nation. My discussion will be perhaps a little broader, looking at what I think needs to be done in terms of attitude.

If we look at the national energy policy—and I feel the Nation as a whole has forgotten the lessons of the 1970's—we seem to have a feeling there is no energy crisis any more. These projections are not justified by either past history or projected future events that are likely to happen.

I would like to call your attention to three things.

No. 1 is, the amount of the oil surplus is very small. That could swing the market from a buyer to seller market. It took less than 2 million barrels a day to swing the market in the 1970's. Similarly, a less-than-5-percent change in the oil supply caused a sharp price increase in 1979.

The second thing to keep in mind is that although the world has responded very dramatically to more efficient energy use because of the higher price, the demand reduction for the future will not continue at the rapid pace that it has taken in the past, simply because the easy ones have already been done.

Foremost, we all know the whole world is in a slow economic situation and, as soon as the economy picks up, much of the savings will be washed out by the new energy demand.

In fact, the chief economist of the International Energy Agency has suggested that about a third, maybe even one-half of the energy savings already achieved can be attributed in the OECD countries to the slow economy.

Certainly I think the most important one we must keep in mind is the stability of the world market in the Middle East. I think in today's climate it does not take a lot of reading in the paper to find out how critical an area it is, with Iran and Iraq fighting each other savagely around Basra. There are about a hundred miles between Basra and Kuwait. For us to depend on that area for long-term energy supply is extremely foolish.

I personally am as much a believer in the free market as anyone else, but if the market is free, I ask why are we asking Japan to limit its auto exports to us? Why are we concerned with the cheap steel imports from Europe?

A free market, I submit, will not voluntarily put in a strategic petroleum reserve. That ties up a lot of money with no capital return. However, the SPR has a much greater meaning for the Nation because it has the potential benefit of moderating the effect of short-term interruptions. That interruption moderation benefit, that saving to the economy, makes it worthwhile for the Nation as a whole to develop a strategic petroleum reserve, although it is certainly not economical for the private sector to do so. By the same token, as long as OPEC as a matter of deliberate policy sets oil prices at a level just below alternatives, the free market will never choose an alternative to imported oil.

There is no way for the private sector to make these heavy energy investments over the long term in an uncertain world with manipulated energy prices. We can witness the flock of synfuels projects that have been dropped in the last year led by Exxon in the Colony Shale project. If we continue this trend, these alternatives will not be deployed until there is another oil price spike caused by the instability in the Middle East or by the greed of the OPEC nations.

To me, assuring that the Nation has an adequate and long-term energy supply outweighs all the considerations. I am a strong believer in the development of coal and other fossil resources, especially through the ways of synthetic fuels. I have never advocated we should do that entirely to replace our oil supply or energy supply. I do believe strongly that we should develop these synthetic fuels on a sufficient scale to provide a technology base and to act as a cap against oil price fluctuations.

The very long leadtime which you know takes 20 years to build a plant, 20, 30 years for an industry to be built, these leadtimes mean that we must have a steady Federal national energy policy support for it to happen. Therefore, in this case I think a national policy must intrude into the marketplace and set priorities. The private sector can never factor national needs into their investment decisions.

I am not in favor of having the Government go ahead and produce energy or having the Government owning and operating plants. I am pleading for a sustained long-term policy that assures these investments to the private sector that can be made and to allow incentives such as price guarantees, loan guarantees, tax credits to be maintained.

I feel if we launch a synfuels industry that can generate a capacity of something like 1 million barrels of oil per day equivalent capacity, and have that onstream within a decade or so, that investment which, when you calculate it, costs no more than the strategic petroleum reserve will have a much stronger impact on stabilizing the world oil prices than the SPR.

I think the SPR is a passive way of stabilizing oil prices. Synfuels production is an active way. Oil producers in the world recognize that.

I feel a growing synfuels industry, coupled with a strong and sustained research and development program to assure a continuing flow of improvements and innovations, will be the most effective insurance the Nation can take against oil-related economic disruptions. I look upon this in the same way as I look upon the massive defense outlay which we all support, which is again an insurance policy which we hope we will never have to use.

I would like to turn for a few moments to the energy R&D scene. As you know, the current Federal policy calls for efforts toward long-term, high-risk research and we expect the private sector to pick up much of the energy RD&D carried out by the Energy Department.

Especially in today's slow economy. I am concerned, like the previous speaker, that with the reduced Government support in energy R&D, there will be an energy technology gap created. To reduce support even in the short-term period will create a dissolving of centers of excellence, of technical personnel, and dispersing of highly-qualified people to other endeavors.

Once we do that, we have to spend a decade to train new people, give them hands-on experience, before they can contribute to the development of energy technology. I think with the shortsighted thrust of the current energy policy, it would be easy to lose a decade in this energy technology gap.

I would like to finally spend a few minutes talking about an enlightening study by the OECD done a year ago on comparing the relationship between investment in energy R&D, the total energy systems cost, and national security for the 15 International Energy Agency members, including the United States, over a 40-year period between now, 1980, and the year 2020.

In making the study, the OECD equated national security with reduced dependence on imported oil. The study begins by noting that even though oil imports would decrease as the price increases, and therefore reduce the dependence of the OECD countries on imported oil, that pace still leaves OECD countries too vulnerable to supply disruptions.

Therefore, the OECD made a study and looked at ways to substantially decrease their oil imports. They concluded that by accelerated development and deployment of new supply and conservation technologies, the OECD countries can look forward to something like a 30-percent decrease of the cumulative imports over the 40-year period. However, implementing such a program will require a very strong effort by member nations to increase public and private awareness and public and private funding as well as overcoming regulatory, legal, and pricing barriers.

It further assumes a willingness by all the nations to pay up to a $7.50 premium over oil imports to get these technologies in place.

The bottom line is, when you add up all the system costs, the scenario is $1.8 trillion cheaper than the cost of a policy that minimizes oil imports without accelerating technology development.

The conclusion is inescapable, that the OECD countries realize that the accelerated technology path must be followed.

We at IGT have done a study. The IEA did a similar study recently looking at the total cost of imported oil on a society through the effect on employment, inflation, and national security. Both of us come up with an estimate that it costs society as a whole something on the order of $100 per barrel of oil when in fact the actual costs, the direct cost out of pocket is on the order of $35. The unfortunate thing is, instead of accelerating energy technology, we are decelerating.

I would like to close by citing a few examples of the kind of work we are doing. Our work which has been operating under a coordinated Federal energy R&D program had coal gasification of Midwest coal to produce SNG and medium Btu gas. These programs have been terminated. We are the first one to produce peat to SNG and opening up another major source for the American user to use in the future, but that effort has been cut short.

We pioneered the development of hydrogen retorting of eastern oil shale. That area is now receiving very little attention. We learned a lot about geopressurized aquifers in tight gas formations. These have been abandoned by the Government to the private sector which it has not taken over yet.

On the utilization side, we need a second generation molten carbonate fuel cell that can use coal as fuel through gasification. But the funding level has been sharply reduced.

On the conservation side, we are looking at thermal energy storage in brick kilns. That effort has been decimated. It has been reduced by a factor of 10. We were conducting a long-range, high risk fundamental research on support studies to improve environmental design data, catalyst development related to coal conversion. That effort has been greatly slashed.

Above all, compounding these funding cuts has been the plan by the administration to dismantle the Department of Energy, a plan which has received very little congressional support but which has seriously disrupted what few activities there are in DOE in the nonnuclear areas. I have been strongly against this plan. I feel that a nation like ours needs a focus on energy, both for policy, planning, and for the management of energy RD&D.

I feel energy is too critical to be relegated to a sub-cabinet level, an action inconsistent with the national policy to reduce dependence on foreign energy supplies.

In closing, I would like to point out a few things that ought to be major elements in our energy policy. One, we ought to recognize we will continue to have an energy problem until energy imports can be reduced to a level such that when such imports are totally disrupted, we can still manage as a nation.

Second, we must recognize importing energy imposes a cost upon the economy and national security which is higher than the direct cost of oil. Even this cost is low if we consider what could happen to the free world when supply disruptions occur.

We must recognize energy supply R&D must extend over decades to provide steady support. Energy R&D cannot be turned on and off like a spigot because the oil price in the world changes a little bit. We must take energy R&D in a balanced fashion to look at all the resources the Nation needs.

Recently, DOE's in-house Energy Research Advisory Board pointed out a disproportionate share of Federal energy research dollars is directed toward electric power generation at the expense of the others.

Finally, although we know that private enterprise must participate to the maximum extent possible in the development of new energy technologies, Government support must be recognized to be indispensable, when the cost of commercial demonstration is higher than what the private sector could afford.

In today's climate of high interest rates, industrial management is forced to focus on short-term, low risk projects. Even demonstrated technologies are having a difficult time being justified on the balance sheet because of the requirements of immediate profitability.

Without Government support, policy support as well as financial support, sufficient long-term investment will not be made. I think we as a Nation will suffer the consequences.

I thank you for giving me this opportunity to be here. I would be happy to answer any questions.

[The prepared statement of Dr. Lee follows:]

STATEMENT BY BERNARD S. LEE, PRESIDENT, INSTITUTE OF GAS TECHNOLOGY

My name is Bernard S. Lee. I am president of the Institute of Gas Technology, a not-for-profit energy R&D organization affiliated with the Illinois Institute of Technology in Chicago. IGT has specialized in energy RD&D and energy-related education programs for over 40 years. I will provide you today with my assessment of the energy problems facing the world and the United States and my thoughts on the appropriate role of the federal government in energy RD&D.

NATIONAL POLICY

I am distressed that we seem to be unable to learn from near-term past experiences. The two major oil price shocks of the 1970's are apparently considered as ancient history, and many seem to have forgotten their traumatic and lasting effect on the economies of the world. We seem to have let the current world surplus of crude oil lull us into a complacency which is not justified either in terms of past history or likely projections for the future. First, we should constantly remind ourselves of how small the so-called "oil glut" is. It took an oil surplus of only 2 million barrels per day—1.5 percent of the world's annual energy consumption and 3.5 percent of its oil use—to transform the world oil market from a seller's to a buyer's market in 1981. Similarly, a loss of less than 5 percent of world oil supply motivated the sharp price escalation of 1979–1980.

The whole world has responded dramatically to the high energy prices. More efficient use of energy will be the way of life for the future. Unfortunately, this impetus is frequently blunted by the human predisposition to relax digilence in developing long-range energy alternatives when presented with temporarily soft oil prices. Demand reduction will not continue at the same rapid pace as the less expensive conservation measures are implemented, such as housekeeping in industry, initial improvements in auto efficiency, and industrial co-generation. One major reason for the reduced energy demand in the West has been the economic slowdown. The chief economist of the International Energy Agency believes it may account for one-third to one-half of the energy savings already realized by the OECD. Obviously, this trend will be reversed once the economy picks up. Data Resources International predicts that energy consumption in Europe will be 50 percent higher than 1980 levels by the end of the century.

Most importantly, the stability of the present world oil market is extremely fragile. The Middle East is like a powder keg with a lit fuse. The fundamentalist Islamic change in Iran has been sufficient cause for concern already for all the Islamic nations in that area. Now the savage battles between Iran and Iraq near Basra assume ominous proportions because only a scant 100 miles separate Basra from Kuwait, with nothing to stop the Iranians if they break through. Add to this the Israeli-PLO confrontation in West Beirut, and we should know that to depend on this volatile area for our energy is foolish.

Nor should be forget that one of the main motivations for OPEC's moderate attitude toward price is fear—fear that the West will develop alternate energy sources that could put it out of business as a cartel, or at least act as a constraint on its control of pricing. Sheik Yamani, the Saudi oil minister, is on record as saying: "If we force the West to invest heavily in finding alternative sources of energy, they will. This would take no more than seven years and would result in reducing (the West's) dependence on oil as a source of energy to a point that will jeopardize Saudi Arabia's interest."

In assessing the U.S. situation, I have always been an advocate of letting free-market forces work, for that has been the mainspring of our country's wealth and greatness. At the same, time, though, one should recognize that our free-market economy has never been totally free. We have a long tradition of peace-time public investment in areas that are vital to our well-being, security, and prestige as a nation. The national highway system, support for the farm industry, space programs, and, of course, defense, are a few that come to mind. These are national decisions which transcend the free market and which must be taken up by society as a whole.

Energy is so vital and so central to the power balance between the U.S. and the U.S.S.R. and to the economic stability of the Western World that the Administration must place the same priority on energy as it does on defense. A consistent energy policy that makes America less dependent on the volatile Middle East would strengthen our position as the leader of the Western World, and also the position of all our allies. An insecure and uncertain energy supply carries with it not only the direct cost of oil imports, but also the burden borne by society of inflation, unemployment, currency leakage and national security risks. These factors do not enter into the decisions for private investment, yet are vital in public-sector decisions.

A free market would not voluntarily put in a strategic petroleum reserve because the money is tied up with no return. However, even though it is unproductively tying up large amounts of capital, the SPR could have the stabilizing effect of allowing the nation to ride through moderate interruptions of oil imports. That benefit of avoiding the disruption of our economy makes it worthwhile for the nation to invest in an SPR.

By the same token, so long as OPEC, as a matter of deliberate policy, sets its oil prices at a level just below the alternatives which the Western World would otherwise deploy, it is obviously not possible for the free market to choose an energy alternative to oil imports. There is no way for the private energy sector to make heavy investment over a long time in an uncertain world with manipulated energy prices. Witness the flock of synfuels projects abandoned by the private sector in the last year, including the Exxon pullout of the Colony shale project. If we continue with this trend these alternatives will not be deployed until there is another oil price spike due to either Mideast instability or OPEC greed. When that happens, the nation will be either once again exposed to tremendous economic loss or be dangerously exposed with an inadequate indigenous energy base.

With respect to energy, I am unquestionably a "supply sider", because to me, insuring an adequate and secure supply outweighs all other considerations. Yet, indispensable as I believe synthetic fuels to be, I have never advocated that they should replace our entire energy supply. Rather, we must have synthetics deployed on a sufficient scale to provide a technology base and to act as a cap against oil price fluctuations. The current transitory surplus of oil on the world market solves no long-range problems for the Western World, which must still develop indigenous energy supplies as rapidly as possible. In fact, we should regard this opportunity as a breathing space to put alternative sources in place. The lead time dictates that we must start now to build plants. It takes at least a decade before a synthetic fuels plant can come on-stream and at least two to three decades before the industry can get on the "learning curve" and establish a reasonable basic industry. The long lead time and massive investments required, and the assurance of sustained policy support before these investments can be made, put the decision to start a synfuels industry necessarily in the hands of the government. National policy must intrude into the marketplace and establish priority because the private sector can never factor national needs into investment decisions.

I am not in favor of government-owned and operated plants, or the entry of the government into the marketplace as a producer. However, sustained policies that provide the assurance for long-term investment to the private sector, and incentives such as loan guarantees, price supports, and tax credits, are clearly needed. If we launch the synfuels industry so that a productive capacity of one million barrels per day of oil equivalent is onstream in a decade or so, that investment, costing no more than the SPR, would have a stronger impact on stabilizing oil prices than the SPR. The SPR is passive resistance, while synfuels production is active.

A going synfuels industry, coupled with sustained research and development programs to assure a continuing flow of improvements and innovations, would be the most effective insurance the nation can provide against oil-related economic disruptions. It would serve the same purpose as the massive defense outlay, which we hope will act as an insurance policy but will never need to be used.

ENERGY R&D

In the area of energy R&D, the extensive cuts in DOE's non-weapons energy R&D budget in 1981 and 1982 and those planned for 1983 will have the effect of reducing Federal spending nearly 60 percent over the three-year period. In fossil energy, the 1983 proposed budget of $107 million is one-fourth of the 1982 level. Whether industry can or will fill the gap is problematic. My judgment is that it cannot.

Current government energy policy is directed toward funding long-term high-risk research, with the expectation that private industry will start funding much energy RD&D that was formerly carried out by the Department of Energy. Government involvement will focus on the areas of basic science and applied research, leading toward, and perhaps including, proof-of-concept. Process development and demonstration, which are the necessary precursors of commercialization, would be left to the private sector.

My concern is for the preservation of the continuity of effort from laboratory or bench-scale through the larger process development units, pilot plants, and then to the size required to assess commercial and technological feasibility. While I strongly support participation by private-enterprise to the maximum extent possible in the development of new energy technologies, I believe we must be realistic about the need for government support of high risk new technologies where the cost to get to commercial demonstration (even with tax incentives, loan guarantees, and price guarantees) is so high that few, if any, major companies can support such efforts.

I am also concerned that with diminished government support for energy research and development, especially development, an "energy technology gap" will be created. Reduced support of energy technology development for even a few years will surely result in the dissolution of centers of technical capability and the dispersal of highly qualified technical personnel to other endeavors. In that case, an entire new generation of technical and scientific personnel will have to be trained again and given sufficient practical experience before it can contribute to energy technology development programs. In short, an "energy technology gap" of at least a decade could result from the current short-sighted thrust of the government's energy programs. The new technology necessary to meet future energy needs cannot be provided by turning energy RD&D on and off like a faucet in response to short-term fluctuations in world energy supplies and prices over which we have little, if any, control.

Over a year ago, the OECD did a rather complex analysis of the relationship between investment in energy RD&D, total energy system costs, and national security in the 15 IEA member nations over a 40-year period ending in 2020. It equated national security with reduced dependence on imported oil. The study begins by noting that although oil imports will continue to decline, even at today's pace of R&D and commercialization efforts, the rate of decrease would still leave the IEA too vulnerable to supply disruptions. After examining scenarios that look at different tradeoffs between costs and security of supply, the OECD concludes that imports could be substantially reduced by some 90 billion barrels—30 percent of cumulative imports over the 40-year period—by the accelerated development and deployment of promising new supply and conservation technologies. The implementation of such a program would require strenuous efforts by member nations to increase public and private sector spending on R&D and overcome legal, regulatory, and pricing barriers to their commercialization. It also assumes a willingness to pay a premium of up to \$7.50/bbl above the cost of imported oil for the new technologies. The total system costs would be about \$1.8 trillion less than the costs under a policy of minimizing oil imports without accelerating new technologies. The report concludes that "it seems mandatory that an accelerated technology path must be pursued. The IEA countries cannot continue on a non-accelerated technology path; the risks are too great and the foregone potential benefits too large." We at IGT have attempted to evaluate the external costs of importing oil; that is, their effects on employment, inflation, and the national security. We concluded that if these factors were quantified, the real price of a barrel of oil to the economy is on the order of \$80–\$110. The IEA took a similar approach in its latest review of its members' programs; it estimated that the effect of the 1979 oil price shock reduced its members 1981 GNP by as much as 10%, or \$1 trillion. This estimate derives from IEA's consideration of internal impacts such as inflation and national security, as well as the transfer of real wealth from consumers to oil producers and the loss of aggregate demand caused by unspent surpluses of the OPEC countries. Applied to OECD oil imports, the total rest cost of a barrel of oil to the OECD economy is around \$100, in the same range as the IGT estimate.

But instead of accelerating, we are decelerating energy R&D. Let me give you specific examples of programs in which IGT was engaged under a coordinated federal energy R&D program. Our pilot-plant coal gasification projects for producing SNG and medium-Btu gas have all been terminated. We achieved the first pilot-plant production of peat to SNG, thus opening up another major energy source to American users, but that has been cut short also. We pioneered the development of hydrogen-retorting of Eastern oil shale to make its recovery economic, but little attention is given to this field now. We learned much in geopressured aquifers and tight gas formations, but these are abandoned by the government so the private sector can take over, which it has not. We need a second-generation molten-carbonate fuel cell that can efficiently use coal, through gasification and cogeneration, but the funding level has been sharply reduced. We need thermal energy storage for conservation in cyclic heating applications, but that effort has been decimated. We were conducting multi-element support studies to provide engineering data for improved process design and to develop catalysts and treatment schemes for enhanced environmental control in coal-conversion plants, but these projects have been slashed even though they are long-term and high-risk.

Compounding the situation is the plan to dismantle the Department of Energy, a plan which has received little Congressional support, but which has seriously disrupted what few activities there are in the DOE in the non-nuclear areas. I have been strongly against this plan because we need a national focus on energy, both for policy and planning, and for RD&D management. Energy is too critical to be relegated to sub-cabinet level, an action that is inconsistent with a national policy to reduce dependence upon foreign energy supplies.

CONCLUSION

In summary, in shaping a responsible U.S. role in the world energy context, our energy policy must recognize that we will have an energy problem until energy imports are reduced to a level which is manageable in the event of their loss.

We must acknowledge that imported energy imposes a cost upon our economy and national security that is much higher than the direct cost of oil and that even this high cost is minor compared to what could happen to the free world in the event of major energy supply disruptions.

It must recognize that a sustained national effort extending over decades is needed to provide adequate energy supplies for the long-term. Energy R&D must be insulated from the vagaries of the world oil market.

It must ensure that the energy R&D effort is balanced with respect to the principal energy sources that we will use for the next 50 years at least. As pointed out recently by DOE's Energy Research Advisory Board, a disproportionate share of federal research funding is directed toward electric power generation at present.

Finally, it must recognize that while private enterprise must participate to the maximum extent possible in the development of new energy technologies, government support is indispensable where the costs of commercial demonstration are higher than what the private sector could afford. In an era of high interest rates, industrial management is forced to focus on short-term, low-risk ventures. Even commercially-proven technologies are difficult to justify on the balance sheet when immediate profitability is required from the massive capital outlays. Without government assistance, sufficient long-term supply investments will not be made.

Thank you for giving me this opportunity to express my views.

DR. BERNARD S. LEE, PRESIDENT, INSTITUTE OF GAS TECHNOLOGY

PRESENT DUTIES

As chief executive officer, Dr. Lee is responsible for all IGT operations. He is a member of IGT's Board of Trustees and Executive Committee; he also serves as a Director of GDC, Inc., IGT's wholly-owned subsidiary, and as a member of its Executive Committee. IGT is a not-for-profit, Membership organization founded in 1941 to conduct research into a variety of energy conversion processes and provide energy education and information services.

EXPERIENCE AT IGT

Dr. Lee joined IGT in 1965 and has been directly involved in the development of all of IGT's synthetic fuels processes. He was named vice president and head of the Process Research Division in 1976, executive vice president in 1977, and president in 1978.

EDUCATION AND PROFESSIONAL ACTIVITIES

Dr. Lee was awarded a Bachelor's degree and a Doctorate in Chemical Engineering from the Polytechnic Institute of Brooklyn (now Polytechnic Institute of New York) in 1956 and 1960, respectively.

He is a registered professional engineer in New York and Illinois, a Fellow of the American Institute of Chemical Engineers, and a member of the American Chemical Society, the American Institute of Mining, Metallurgical, and Petroleum Engineers, the American Association for the Advancement of Science, and the American Gas Association.

He is a Trustee of the Illinois Institute of Technology.

In 1978, Dr. Lee was awarded the Chemical Engineering (a McGraw-Hill publication) Personal Achievement Award in Chemical Engineering.

PERSONAL

Dr. Lee was born in Nanjing, China in 1934 and is now a U.S. citizen. He is married and the father of three children.

Mr. YOUNG. Dr. Shannon.

Dr. SHANNON. Thank you very much, Mr. Chairman.

I represent a not-for-profit research institute which is involved in both basic and applied R&D on coal combustion and energy systems. This afternoon I will discuss some research topics that I think need to be included in an integrated R&D program in basic coal science.

The principal problems in coal combustion remain what they have been, for many years. First, we need to understand the principal mechanisms involved in the combustion and decomposition of a single piece of coal. Second, we need to know how to interpolate or extrapolate with confidence from a group of well studied coals to predict the behavior of uninvestigated coals.

I should stress we need to do both basic and applied R&D. In the basic research category, we need to improve our understanding of the structure and properties of coal. Improved understanding is necessary on several counts. First, as a means of characterizing a specific coal. Second, as a means of relating the properties of one coal to another coal. Third, to provide a basis for evaluating and predicting the reactivity behavior of coals.

Research should be focused on determining the key features that affect coal utility and reactivity. Included are such things as determinations of the variations of hetroatoms, carbon skeletons, general mineral content, physical structure, and volatile products from various coals.

Research on these topics is underway at various industrial laboratories, universities, and independent research facilities. I believe that Government-sponsored R&D should be structured to complement and extend this ongoing work.

In parallel with the research on coal structure properties, basic research on coal combustion should be supported with the objective of improving the understanding of the chemical and physical processes involved. The schematic diagram presented by Dr. Hartley highlights the overall processes. Basic experimental and computational studies on some of the subscale processes that he highlighted need to be conducted. Such things as chemical kinetics, ignition, and quenching are among topics that need further study if we are to understand how to use coal to the maximum benefit.

Selected topics that need to be looked at include the mechanisms and rates of volatiles generation as related to coal characteristics, the fate of fuel nitrogen, and the kinetics of NO_x formation.

The need for applied R&D work in coal combustion stems from the fact that coal characteristics are not well enough understood for quantitative prediction of performance parameters. At present, we have a limited ability to predict how a new system or a furnace will perform under novel or new constraints. Small-scale and pilot-scale systems suitable for investigation of novel combusters, and coal-based fuels aimed at retrofit of oil-designed boilers need to be built.

The main thrust of the applied R&D should be the development of a technology base for conventional and advanced combustion concepts, and a demonstration of the ability to use coal and coal slurries in various combustion configurations, including various types of boilers and heaters.

The TVA's 20-megawatt demonstration fluidized bed combustion pilot plant which began operations on June 1, 1982, is an excellent example of this kind of facility.

In conclusion, an improved understanding of the processes related to combustion efficiency, pollutant formation, and equipment reliability should result from the applied and basic R&D. This improved understanding could in turn lead to a significant expansion of the technology base for the direct utilization of coal. Overall, I would see the Federal Government as an integrating and driving force in both the basic and applied R&D activity that needs to be conducted.

[The prepared statement of Dr. Shannon follows:]

R & D NEEDS IN COAL COMBUSTION

L. J. SHANNON

Executive Director, Engineering and Applied Sciences Group
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Introduction

Coal is the nation's most abundant fossil fuel, and there is little doubt that coal can provide a major portion of this country's energy in the near and mid-term. The substitution of coal for oil and natural gas on a large scale, either directly or through synthetic coal-derived substitutes, could solve many of the nation's energy problems. The simple arithmetic of availability, however, does not tell the whole story. Doubling or tripling the use of coal will take time, considerable investments, and determined efforts to solve an array of technical, economic, and environmental problems.

Additional research will be required if coal is to achieve the levels of use frequently predicted. Research needs exist in coal extraction or production, direct coal combustion, and coal conversion. The remainder of my remarks will address some of the key research needs in the area of direct coal combustion.

Research Needs in Direct Coal Combustion

Coal, especially pulverized coal, has been utilized as a fuel for centuries. Furthermore, there exist in operation throughout the world, thousands of combustion units designed to raise steam, utilizing pulverized coal as the primary fuel. On the whole, these units work well and efficiently. This being the case, one may question the need to undertake research programs directed towards the understanding of fundamental mechanisms during coal combustion. What new facets have emerged to require a deeper understanding of the fundamental processes involved?

Three new problem areas can be identified. First, a rapidly changing energy supply situation has required operators of combustion equipment designed for liquid or gaseous fuels to consider switching to solid fuels. The operator is then forced to determine: (1) whether he should burn conventional pulverized coal after incorporating drastic design changes in his equipment; (2) whether he can use his existing unit, but at a reduced load; or (3) whether he should attempt to fire coal in an unconventional mode, such as with ultra-fine particles (less than 400 mesh) or mixed with oil or water to form a slurry. The operator will soon find that basic technical information to guide his decision-making process is presently unavailable.

Second, increased utilization of coal for new combustion units has led to the introduction of coal types, different (usually of lower quality) from those used in the past. Predictive tools to extrapolate experience gleaned from one coal-type to one radically different are unavailable. The designer uses his experience with conventional coal-types, and hopes that the untested coal will cause no unusual problems.

Third, environmental considerations have required combustion modifications for pollutant emission abatement. Nitrogen oxides abatement can be accomplished economically only through prevention of their formation during the combustion process, and not through stack-gas removal.

Both basic and applied R & D related to direct coal combustion is needed. Selected topics in both areas are presented in the following sections.

Basic Research in Coal Combustion

The principal problems in coal combustion remain what they have been for many years. First, we need to complete our understanding of the principal mechanisms governing reactions in the case of a single coal. Second, we need to know how to interpolate or extrapolate with confidence from a group of well-studied coals to predict behavior of new, uninvestigated coals. A prime requirement of the second problem and to a lesser extent of the first is a need to better understand the structure and properties of coal.

Research into the fundamentals of coal structure and chemistry is underway at various industrial laboratories, universities and independent research facilities. Research in this area should receive strong support from the federal sector. Research supported by government funds should be focused on determining the key structural features that affect coal utility and reactivity. Key features include determination of heteroatoms, carbon skeletons, mineral matter, physical structure, and volatile products.

Basic research on coal combustion should be directed to improving understanding of the chemical and physical processes involved. Basic experimental and computational studies of subscale processes, e.g. chemical kinetics, laminar and turbulent fluid mechanics, mixing, ignition, and quenching are among the research topics requiring further study. Some research topics recommended for study are:

- Mechanisms and Rates of Volatiles Generation as Related to Coal Characteristics
- Mechanisms and Rates of Coal Nitrogen and Sulfur Release
- Fate of Fuel Nitrogen and Kinetics of NO_x formation.
- Mechanisms and Rates of Char Combustion as Related to Parent Coal

The objective of basic research should be to provide supporting data, diagnostic tools, and engineering models which would form the technical basis for assessment, optimization, and implementation of advanced coal combustion systems.

Applied Research in Coal Combustion

The need for applied R & D work in coal combustion stems from the renewed emphasis on the use of coal as a primary fuel in utility and industrial boilers. The problems associated with using coal, probably pulverized coal, in industrial boilers and large fired heaters represents a focal point for applied research.

Small-scale and pilot-scale systems suitable for investigations of novel combustors and coal-based fuels aimed at retrofit of oil-designed boilers and processes need to be built. These facilities would permit engineers and scientists to investigate problems such as slagging and fouling in the combustion of various coals and pollutant formation and control, and to apply additives and different burning techniques to "problem" coals. The main thrust of this research should be the development of a technology base for conventional and advanced combustion concepts and the demonstration of the ability to use coal and coal slurries in various combustion configurators, boilers, and heaters. The improved understanding of the processes related to combustion efficiency, pollutant formation and equipment reliability would result from the R & D programs outlined above. This improved understanding would in turn lead to a significant expansion of the technology base for the direct utilization of coal.

LARRY J. SHANNON
Executive Director
Engineering and Applied Sciences

Dr. Shannon is responsible for the planning, coordination, and direction of the Engineering and Applied Sciences group at MRI. The group's areas of expertise include engineering sciences, waste-to-energy systems, coal sciences, energy management, process engineering, automated production, instrumentation, polymer technology, product development, materials engineering, and technology evaluation.

Dr. Shannon has extensive experience in the environmental sciences and energy systems. He has directed and participated in programs dealing with the systematic study of processes, plants, and industries and their interaction with the environment.

Before joining the MRI staff in 1969, Dr. Shannon spent 6 years as a senior chemical engineer with United Technology Center, a division of United Technologies Corporation, where he was involved in a variety of programs in the fields of combustion dynamics and solid rocket combustion. He was also principal scientist on an Air Force Office of Scientific Research program to define the mechanisms of solid propellant ignition. During the course of these programs, he was involved in the investigation of composite solid propellant and monopropellant deflagration and decomposition processes; analysis of advance propulsion systems, and solid propellant burning rate catalysis.

Dr. Shannon is the author or coauthor of 25 published technical articles and is coauthor of chapters in five technical books in the fields of air pollution and the combustion dynamics of solid rocket propellants. He is a member of Air Pollution Control Association, American Institute of Aeronautics and Astronautics, and Sigma Xi, (Scientific Research Society of North America). Dr. Shannon received the B.S. in Chemical Engineering (1959) from Seattle University and the Ph.D. in Chemical Engineering (1963) from the University of California-Berkeley.

Mr. Young. Thank you, Dr. Shannon.

We appreciate the testimony of all of the members of the panel today. You can appreciate some of the members have been working very diligently in Congress, so they are spread out all over the Nation.

I do have a series of questions I would like to ask some of the members of the panel. We appreciate your comments to the questions they can be made a part of the record, and they will be made available to the other members of the committee who could not be here today.

On behalf of the chairman of the full committee and the chairman of the subcommittee, I want to thank you all very much for your appearance here today. I will now proceed with some of the questions.

We will start with Dan Hartley.

How much of the funding, Dr. Hartley, of the DOE for 1981, 1982, and 1983 is going into the coal combustion program?

Dr. Hartley. The total AR&TD program in fossil energy in 1981, was on the order of $50 million; in 1982, it is about half of that. That is broken up into several subcategories, only one of which is combustion.

Mr. Young. That seems to be going down, too, very rapidly.

Dr. Hartley. Yes. It is going down very fast. The combustion part of AR&TD is several million dollars. It is still the largest source of funding for coal combustion in this country.

EPA has a program that is on the order of $1 million a year to look at coal combustion and oil and gas combustion. So that doesn't cover very much.

Mr. Young. What do you see with the amount of RIF's in the reorganization of the Department of Energy as it relates to the coal combustion activity?

Dr. Hartley. It hurts it quite dramatically. A lot of the younger, more innovative thinkers in the fossil energy organization were, of course, eliminated because of the normal civil service way of RIF'ing people. I think that is a shame. I understand that some of that is under reconsideration. I hope that some of those people are reinstated in their positions.

There are several people at DOE who are very foresighted and do have very good ideas, and very strong ideals. I hope for them the best of success.

Mr. Young. We will see what the committee can do to have people pay a little more attention to the very important need for keeping the teams together as we look down the road to the future.

You mentioned the specific recommendation—would you tell us what the specific recommendations of the congressional Joint Economic Committee were with regard to coal combustion? On what did they base most of their recommendations?

Dr. Hartley. They didn't put a dollar recommendation on coal combustion. They just highlighted that as an example of the major area they saw needed work. They also discussed the need for advanced equipment to aid in mining and refining of coal. So it was not exclusive to that field at all.

They did seem to highlight it as a single major item. They talk about a $1 billion program. That is on the order of the 1981 total fossil energy budget. My sense of it is that they wanted to see that level of effort again, but with more emphasis on the fundamental issues, one of which is combustion.

I do not know what they drew their information from. This only came out 2 weeks ago. I read a summary of it in my office the day I wrote the testimony. So I do not know all the details behind it.

Mr. YOUNG. In other testimony before the committee there has been a discussion of the need for a coal data bank to characterize various types of coal for scientific and engineering purposes. Do you think this is necessary and a practical approach?

Dr. HARTLEY. Very definitely. In fact, again giving credit to the AR&TD program within fossil energy, that was one of their major objectives also, aiding in the formation of that coal bank. I think all the fundamental information we talk about in understanding coal combustion cannot make sense until we can relate it back to the fundamental properties of coal itself. That is the purpose of the coal bank.

Mr. YOUNG. Dr. Hartley, are you the one that testified to the fact that there were 350 million tons of coal to be exported? Is that by the year 2000?

Dr. HARTLEY. Yes. There are two sources of that. One, the Joint Economic Committee stated that and the MIT world coal study stated that as the most probable event for the year 2000.

Mr. YOUNG. Thank you very much.

Mr. Mead, we are very interested in the other side of the river, too, on almost every project, except the airport over here which apparently people had problems getting in and out of today. Other than that, we are vitally interested in the coal resources of the State of Illinois.

I think your testimony was very good. Let's see if we can get a couple of questions for the record.

How would you propose to administer a program of providing money to the States, particularly the ones in the Midwest, to do the research and development if we were able to provide some funding?

Mr. MEAD. I think there are two ways but these are not well thought out responses, because obviously this is not a fiscal year 1983 decision.

The first is to follow up on some of the past regional research efforts. I go back again to that 1977 Federal law that mandated university coal research centers. That was a messy, complex review effort that tried to bring universities into federally funded operations. I think with some streamlining, with an emphasis on maybe a State level approach to that kind of grant program, we could get something that the States would be willing to fund jointly with the Federal Government.

I think another way which really puts the emphasis back on the State would be a direct grant to projects that have been approved, or are in an advanced planning stage by the State.

I hate to use the New Federalism, but there seems to be a definite trend, phrase which I think preceded President Reagan, to evolve decisionmaking powers back to the State with the Federal money coming in as, at least, the initial motivator.

I think there are some energy programs where that could work. I know that the State of Illinois is certainly interested in coal development, but other States, such as the New England States, may be interested in pursuing gas conservation technologies. Institutions that may well be in existence already in those states are certainly ripe for funding from the Federal budget.

I think traditionally these States have been viewed as being poor decisionmakers in terms of technology and general development policy. But the opposite I believe has been true, at least in the Midwest. Some of these States have made good decisions and have good projects under way.

Mr. YOUNG. You already answered the third question then. How could duplication be avoided in the activities from State to State. I think your answer pretty well lets the State do as they would want.

Mr. MEAD. I think duplication is a problem that certainly exists today. More importantly, there are so many gaps in what is going on nationwide, giving the States a little more responsibility may help to fill those gaps.

I think the danger of duplication could be minimized with some kind of clearinghouse. I know all the various research institutions and regulatory commissions in the several States watch what the others are doing very closely, just as a researcher would go through a thorough literature search before he came up with a new proposal.

So I think the risks of duplication are certainly there, but they are there today.

Mr. YOUNG. Since a State shows such a need—particularly your State, the importance of high sulfur coal on the State economy—why does the Federal Government have to get involved as far as your own research and development is concerned? Surely the State of Illinois with the tremendous availability and resources that are apparently under the ground—why should we be that involved in the research and development funding?

Mr. MEAD. I guess right now one of the reasons is that we have a pump that needs to be primed. There is a lot of money available from a resource like coal, and yet the availability from the private sector and I think from any State government through the revenue base hasn't been adequate, partly because there hasn't been a demonstration that such things can get off the ground.

Unfortunately, the gentleman from Peabody is no longer here. I have often wondered why the coal companies have been so reluctant to invest heavily in their own future. It seems like a natural thing to do. The electric utility companies did it. A lot of the high technology companies did it. Certainly the oil companies have done it. We would love to get some of that money for coal.

We sincerely wish that we had a dozen more Kilngases on the way. Unfortunately, the private sector still needs that push and we need more liquid assets to prime that pump.

Mr. YOUNG. Very good. I know we are trying to work on—I guess the word is rail relocation, railroad consolidation in the metropolitan St. Louis area to move our goods through both sides of the river a little bit faster. There are all kinds of incentives, but we are just having a terrible time getting them to invest their own money back into the building up of their own facilities.

It seems to me it would be a better utilization of some of their money, too, to be able to move the coal or grain or whatever it might be a little faster through the St. Louis and east St. Louis yards.

I can appreciate some of the problems there.

Dr. Lee, I heard from Armand Hammer, I think, just a few days ago or 2 weeks ago on national television. Our first question is how did you rationalize the per barrel cost of oil to the economy of a hundred dollars a barrel. We were saying the price of $35 or $40, which we might see currently, was going to be a hundred dollars in the year 1990, I guess is what he had said.

So the hundred dollars a barrel is a little different in the way you have it built in. What is the background for that?

Dr. LEE. I think—although I didn't hear Dr. Hammer's speech—I think many people tried to project what the cost of a barrel of oil might be in the year 1990 or 2000. We have heard all kinds of numbers going from $35 to $50 to $100. What we are trying to address is that it costs the importing nations as a whole a lot more than just $35 to shell out as a price to pay for the barrel of oil. There is an additional impact.

I think we all agree directionally there is an additional impact on society, whether it be through the outflow of funds through the economy that creates or leads to or contributes to unemployment, currency leakage. These obviously have an impact on the importing nation. Perhaps one the most difficult to quantify is to try to put a number on the cost of supply interruption, otherwise sometimes called a security issue. We tried several things.

If you would like, Mr. Chairman, I can leave you a copy of a study we made a couple of years ago which we issued to the energy community. Many other people have done similar things.

What we tried to do is the following: On a national security issue, we know we are talking about a defense budget of $170, $180 billion. A good portion of that we always hear is aimed to protect the oil tanker lanes, the rapid deployment force. It is difficult to estimate how much of the $170 billion is attributable to such protection.

Take any number, say 5 percent, 10 percent of that is related in some fashion to the oil imports. If we didn't have to be so reliant on that area, maybe you could save that money. Divide that savings by the number of barrels of oil you import, you come out with one of these external costs.

Similarly, you take estimates done by economists both here and overseas on the effect on inflation, unemployment, and come up with these estimates for external costs. The one that is done in Europe by the International Energy Agency, whose chief economist is well known, Dr. Herman Franssen, they looked at the impact on inflation, unemployment, and the transfer of wealth from the consumers to the producers which again depletes and impoverishes the nation that imports it and has a negative impact on the economy.

What we are saying is the real cost—we put a range on it. The real cost is not $35; it is a lot more than $35. I think the direction is correct, because if it were not for the fact that we are just shell-ing out $35, I think the rest of the nations in the world, especially the developing countries, would not be working so hard to try to use whatever indigenous energy resource they have, be it low-grade wood, biomass, the ocean, any of that, and try to do without importing oil because they are less able than we are to afford that kind of luxury.

What we tried to do with that study was point out the fact that there are more things to be considered than just buying a barrel of oil. Other factors must be considered which are the costs that are borne by society as a whole. Therefore, the society as a whole must make a decision to do something about this.

A private investor would only look at it as $35 a barrel. I think the Nation as a whole is going——

Mr. YOUNG. And the Congress in particular, I assume?

Dr. LEE. I hope the Congress representing the people looks at it.

Mr. YOUNG. That is very interesting. We would surely like a copy of the conclusions or the methodology that you used. I know I particularly would like to have a copy of it.

Dr. LEE. I will be glad to leave you a couple of copies. I am not an economist by training. We had our economist teams do it.

Mr. YOUNG. You might have made more sense this afternoon.

Dr. LEE. They did list all the assumptions. You can play with the assumptions.

Mr. YOUNG. Would you care to comment, Dr. Lee, on the operation of the U.S. Synthetic Fuels Corporation and how it fits into the Government program?

Dr. LEE. You mean the current program?

Mr. YOUNG. Yes.

Dr. LEE. Well——

Mr. YOUNG. We haven't heard much from them lately.

Dr. LEE. We all know the DOE has stepped out of the synthetic fuels area, especially in large scale efforts, demonstration. That is to be handled by the Synthetic Fuels Corporation.

I supported the concept of a synthetic fuels corporation. I think it represents one way for the Nation to set a policy and a direction.

Personally, I am pleased with the attitude that is evolving at the SFC vis-a-vis the original view when some of these new members of the management came on board. As you recall, one of the earlier attitudes was their job is to get rid of this operation, stating the Nation doesn't need it.

I think as time went on, the Chairman, the President, the Board members of the SFC have begun to make statements which read: "Yes, there is a place for this." Whether the of oil or oil equivalent of synthetic fuels to be produced must be the target set a few years back, or whether they should scale back some, that is not important.

I think the direction that is taken is that it should be a significant amount of production and it should be a variety of technology, which is the second thing I am pleased to see.

The earlier attitude seemed to be if we are going to build synthetic fuels plants, we ought to copy the South Africans and build more of the same. I think today's attitude is we ought to build a variety of technologies in sizes that are modular and that could be deployed over a wide range of locations.

I think the SFC is moving, in my judgment, much closer to that. My only concern is in the interests of being extremely tight bankers, which is a good virtue, I think they must balance that against the need to get these technologies in place. If the technology is good and needs to be developed some time or other, asking for a little more or less return on investment, I think that is not as important as getting these deployed.

I wish they could let these technologies go into place and we could start learning from these in every aspect, technically, manpowerwise, as well as environmentally, processwise. We can learn a lot from the first few plants that are built.

I am encouraged but I would like to see a little broader deployment.

Mr. YOUNG. The last question, Mr. Stockman has argued that the costs for our independent energy position would put us in a competitive disadvantage with our exported goods and help our Japanese and German competition. Would you care to address that issue at all?

Dr. LEE. You mean if we support the energy industry, our energy costs will be so high that we will be less competitive with the Japanese and Germans?

Mr. YOUNG. Right.

Dr. LEE. Well, without reading the whole context, just listening to that, I would disagree because the Germans and Japanese are very, very actively supporting their energy industry in a massive government-industry coordinated fashion. Anything we do in this country, the Japanese are watching very carefully and absorbing very carefully and perhaps implementing more rapidly than we are.

I do not offhand agree with that statement that adding that element would put us at an uncompetitive level. I think on the contrary by making our energy supply more secure, it gives us a better chance to invest for the longer term domestically, since we have a huge domestic market, as well as making our foreign investment more reliable.

I think there is nothing more uncertain than a climate where nobody invests in anything. That penalty I believe is much more severe than being concerned with the small incremental cost.

Keep in mind, what we are talking about is getting new technology in place. We are not talking about building these plants, 300 all at once. We can learn as we get better. Get better as we do more of it. By the time we deploy these on a massive scale, we will have the improved technologies that will be competitive with all future ones.

Even the OPEC countries recognize all Western nations must have nonoil sources in the next 20 years. They all recognize that. We are not doing anything and 20 years is coming and going pretty quickly.

Mr. YOUNG. You are right. It is 40-odd years since I was chased around the autobahn with a Volkswagen. Volkswagen is American now so it makes hardly any difference. I am sure there is some of that V-2 stuff Werner von Braun was shooting over our head, hoping it had enough power to get to England.

Thank you, Dr. Lee.

Dr. Shannon, the oil-designed boilers are rapidly approaching their useful lifetimes and there has been a reluctance to increase the dependence on oil as a source of energy. Therefore, why do you see long-term research on combustion being within the same time frame to involve retrofit to oil design boilers?

Dr. SHANNON. That is certainly true, there are boilers nearing the end of their useful lifetime. But there are other ones that still have many years of useful life left.

Mr. YOUNG. After all of the activities that have received support from the various Government programs on combustion, slurry fuels, and just plain manufacturers' operating experience, why do you say an operator of combustion equipment does not have the technical information to guide his decisionmaking process to determine what type of process to use?

Dr. SHANNON. Usually he will be faced with a different coal, perhaps a coal than has not been characterized. If that is the case, then he has very few guidelines, if any, to know how to use prior experience to burn that particular kind of coal.

If he is using an Illinois 6 coal which is well characterized, he can feel reasonably confident in designing a system. But if he is to take an uncharacterized coal, it is very difficult to take existing information and design well. It is almost an art rather than a science.

Mr. YOUNG. What progress has been made in coal combustion technology in the past 10 years?

Dr. SHANNON. I think there has been significant progress in the area of fluidized bed combusters which offer applications where you can use different kinds of coals to deal with their problems both environmentally and operationally.

Mr. YOUNG. Do you think we can move faster than we did in the last 20 years in the next 10, let's say?

Dr. SHANNON. With adequate resources, yes.

Mr. YOUNG. It seems to me some of the testimony took us back to 1962. Here we are 20 years later. We haven't gotten very far. I think that is probably what a lot of your testimony related to this afternoon. That figure caught me. Here we are, 20 years later.

As it relates to synthetic fuels, it does not look like we moved at all. Maybe as Dr. Hartley suggested in the research they have done out there on the particles, the different combustion now, I think it would be very, very helpful if we could keep the momentum going. Hopefully in the next 10 years we will be able to make strides that will hopefully start answering some of these questions.

As the testimony keeps building up in this synthetic fuel program, I hope we will learn something.

I was a pipefitter at the Louisiana plant here when they brought equipment over from Germany. That was a Truman situation, I guess. Harry was President from 1948 to 1952. We had a plant here, Louisiana Coppers Co. The next fellow in wasn't from Missouri, he was from Kansas. Where have we come since that process?

Apparently it was a successful process. Here we are way after 1947, still facing this question. I am not sure that the research and development, knowledge that somebody had back in those years has been fully utilized.

Does the staff have any questions?

Well, fine. I want to thank you gentlemen very much for your attendance here. If you want to add anything into the record, we will keep it open so we can include any additional testimony that you would like to submit.

On behalf of the Committee on Science and Technology and the Subcommittee on Energy Development and Application, I want to thank you all very much for your attendance here today.

The hearing is adjourned.

[Whereupon, at 3:10 p.m., the subcommittee was adjourned, subject to the call of the Chair.]

COAL RESEARCH

THURSDAY, SEPTEMBER 16, 1982

House of Representatives,
Committee on Science and Technology,
Subcommittee on Energy Development and Applications,
Washington, D.C.

The subcommittee met, pursuant to notice, at 9:30 a.m., in room 2318, Rayburn House Office Building, Hon. Don Fuqua (chairman of the subcommittee) presiding.

Present: Mr. Winn and Mr. Dunn.

Mr. Fuqua. The subcommittee will be in order.

Our hearing today on coal research is the fourth and last in a series devoted to this subject in the current session of Congress.

Our purposes in conducting these coal research hearings are to identify those national scientific skills available to coal research, to assess the achievements of the current programs, and to determine the Federal role in future coal research in a time of constrained budgets.

We have heard representatives from industry, from universities, and from national laboratories speak on the present extent and the continuing need for coal research.

Three facts are clear:

First, coal is one of America's leading energy resources and its role in our energy mix will increase rapidly in the years ahead.

Second, we need to understand more about coal so that it can be more efficiently and more safely mined, transported, cleaned, burned, and converted to synthetic fuels.

Third, coal is a highly variable resource. Its physical characteristics vary greatly from region to region and even from seam to seam.

Thus, I believe that we must have an aggressive, interdisciplinary coal research program in such key areas as resource characterization, cleaning, combustion, liquefaction, gasification, and instrumentation.

To discuss these issues we have with us today two distinguished panels of individuals from the university and industrial research communities. The first panel consists of Dr. David White, director of MIT's renowned energy laboratory; Dr. Richard Wolfe, vice president for R&D of the United Coal Co.; and Dr. Charles Prater, private consultant on coal research, who also is a member of the group that performed a very valuable service, particularly to our staff and our members, the review of modern physics for the American Physical Society.

Also later will be Dr. Robert H. Davis from Florida State University in Tallahassee, which I am privileged to represent, was also a member of that group, and we will be hearing from them later.

At this time I would like to call on our ranking minority member, Mr. Winn, for any comments that he might wish to make.

Mr. WINN. Thank you, Mr. Chairman, for the opportunity to welcome our witnesses this morning.

As you mentioned earlier, this is the fourth in a series of hearings on coal research. Upon our completion today we will have received valuable testimony from nearly 30 people representing industry, Federal facilities, colleges and universities, and consulting activities.

To date, the advice that we have received from our witnesses has been very beneficial. We expect to summarize all of this information, providing guidance to the members of the committee as we evaluate the Department of Energy coal research program in the future.

Our witnesses thus far have confirmed my concern that we lack much basic knowledge of coal. Present information is adequate if our vast resources of coal will be used only for direct combustion. However, this committee has sponsored a large number of sophisticated processes for converting coal to both gas and liquid.

We certainly believe that efficient conversion requires a much more basic knowledge of the coal resource than we have at this time. So, we anticipate that the Federal role will continue, relating to those long-range, high-risk programs which are necessary to understand our coal resource and which are beyond the justification of industry funding.

I want to thank the witnesses for being with us today. We look forward to your testimony.

Thank you, Mr. Chairman.

Mr. FUQUA. Thank you, Mr. Winn.

Before I recognize Mr. Dunn, without objection permission will be granted to take photographs, recordings, et cetera during the course of the proceedings today.

Mr. Dunn from Michigan.

Mr. DUNN. Mr. Chairman, I have an opening statement, but with respect for the committee's time, why don't I just submit it for the record?

Mr. FUQUA. Without objection.

[The opening statement of Mr. Dunn follows:]

OPENING STATEMENT OF HON. JIM DUNN

Thank you, Mr. Chairman.

This series of hearings on coal research is timely, and you are to be commended for sponsoring this activity.

We are all aware that in the past two years there has been a tremendous change in philosophy at the U.S. Department of Energy. In years, past, the committee has sponsored the design, construction, and operation of some very large development facilities. This has certainly been in response to pressures from many people concerned with the health of the nation's energy program. However, as time has gone by, it has become more apparent that we should increase our knowledge of this vital coal resourece itself.

One would think that, having lived with coal all these years, we would have a full knowledge of its occurrences, its characteristics, its uses, and its potential. However, as I have become more involved in the fossil energy program, I have found that we know very little of the basic nature of coal. So, I have certainly encouraged and supported programs directed at the basic research necessary to define coal more thoroughly. These necessary programs and projects are high risk and they will require a long time for proper definition. However, the payout could be substantial. This appears to be the place where the federal role could be most helpful in the utilization and conversion of coal to direct combustion and gaseous and liquid fuels.

Certainly the information we have received from past witnesses and our witnesses today will provide guidance to us as we evaluate and authorize future Department of Energy fossil programs. Again, thank you for this opportunity to participate and to welcome our witnesses.

Mr. **Fuqua**. The first witness will be Dr. David C. White. Dr. White?

As a matter of fact, why don't all three of the witnesses come forward. Once we hear from you we will then have questions that maybe all three of you may want to participate in.

Dr. White.

STATEMENTS OF DR. DAVID C. WHITE, DIRECTOR, ENERGY LABORATORY, MASSACHUSETTS INSTITUTE OF TECHNOLOGY; DR. RICHARD D. WOLFE, VICE PRESIDENT, RESEARCH AND DEVELOPMENT, UNITED COAL CO.; AND DR. CHARLES D. PRATER, CONSULTANT

Dr. **White**. Good morning. It is a pleasure to be here, and I hope that my testimony will help you gentlemen in your complex task.

In my view, there are three categories in coal R&D that are needed. Some of these are near and midterm and some are long term.

The near-term activities involve coal beneficiation and combustion control, to use coal more effectively in existing coal-fired boilers and to substitute coal for residual oil in all oil-fired boilers. For the midterm, development involving new coal combustion technology should be brought to commercial scale.

The long term is advanced research on coal's structure, chemistry, and chemical pathways for liquefying and gasifying, that is, advanced research that I would imagine this committee would expect me to support.

You are probably surprised that I am in favor of some near- and mid-term technologies as well. The question is why.

The use of coal, at least in the next 20 years, is fundamentally going to be by the electric utilities. There will be modest amounts used in industry, and there will be some liquefied and gasified, but the bulk of coal is going to be used in our electric utility industry.

The kind of technology that is needed both to improve existing facilities and to add new ones to use coal in an environmentally acceptable way involve very large and complex technologies.

Considering the amount of coal used commercially and the maturity of coal combustion, why can't the existing equipment manufacturers and the utilities do any needed development? The problem stems from the fact that we have a regulated industry. Tradeoffs are necessary between social equity for consumers and fair returns to the utilities. The many millions of dollars necessary to bring new technology to commercial scale is in fact not available in current utility rates.

In addition, with the reductions in demand from price increases that have occurred in the last 10 years, there is not the rate of addition of new capacity by the utility industry to give the suppliers of equipment a major driving force to develop new technology.

So, bringing these near-term and mid-term technologies to commercial scale is going to require additional Government funding. Long-term basic research is also needed, the Government should support.

In fact, some part of the long-term research is being done very effectively by the petroleum industry which has an interest in coal-derived fuels. There is almost more fundamental research underway than the near-term/mid-term development of new technology.

For the shorter term development, what is an effective way to have Government involvement? It seems to me that the Electric Power Research Institute, which has been established by the utility industry, can do this type of development effectively.

They already have reasonable development programs underway. Unfortunately, the quantity of work that they can support from utility industry funding is not enough to bring on the new technology to yield improved combustion and reduced emissions from coal used in the plants that will be built in the next 20 years.

So, my recommendation is that this committee and the Government carefully consider ways to augment the developments that the industry already has underway.

The utility industry, EPRI, and the suppliers understand the problems. There has, in the past, been substantial joint funding between DOE and those groups. Most of that is being eliminated. There needs to be careful consideration given to maintaining adequate Government support.

Now, to the domain in which I have personally more interest, the advanced research.

It seems to me that we need to do substantially more in terms of getting our basic scientific community doing work on coal. Our real understanding of coal structure and the methods of transforming by adding hydrogen and breaking coal up into more useful hydrocarbon products is not very advanced.

Most of the technologies that today could be made commercial, though certainly not economically viable, are based on outstanding work done in the 1930's and 1940's by German scientists.

The real contributions that could come from the advances that have occurred in organic chemistry in the last 50 years, the use of the advanced analytical tools—infrared and nuclear magnetic resonance, X-ray and electron microscopy, chromatography and neutron activation analysis—all of these tools, used with the advances in quantum chemical theories, such as frontier orbital interactions, the sophisticated kinetic and stereochemical experiments that one can conduct can give insights and lead, we believe, to new processes that in fact don't exist today.

To do this, you have to have the best minds in both our academic and industrial laboratories working on these problems. I believe it requires young minds and it needs to include ways that those young minds can interact with the mature and experienced technologists.

For that reason, my recommendation is that attention be given to establishing a few very good centers for coal research. This kind of recommendation has been discussed before.

I cited in my written testimony several examples in which attempts were made and they failed. They failed for a multiplicity of reasons, but I really believe that there are existing facilities that, if expanded and structured to encourage industry involvement and oversight, could produce the kinds of research capability that is needed to yield new knowledge and concepts.

One of the reasons I believe that advanced research can produce significant new insights into coal chemistry stems from the work of one of my colleagues at MIT, who, in conjunction with several doctoral students, in the last 3 years has advanced some new and different theories of hydrogen donor pathways in coal. The experimental and theoretical results look interesting and promising.

It is similar work over the next 20 years that may enable us to conceive new technology to liquefy and gasify coal and produce desired hydrocarbons for future uses.

There is one organizational example that I can quote in my own institution in which the National Institutes of Health established in the area of combustion, emissions, and toxicology, long-term programs of support, which have proven to be extremely effective. The kinds of commitments in terms of oversight and long-term funding has made a significant difference and the programs made to date attest to the validity of long-term support of talented and dedicated researchers.

In conclusion, let me mention dollars. As I look at the recommendation from DOE in the areas that are related to what I have discussed, it is about $35 million out of the some $90 million they have recommended. This was the coal technology and coal beneficiation at $9 million, combustion systems at $6 million, and advanced research and technology at $20 million.

My judgment is that 5 to 10 times the amount that is recommended is probably the level needed. I have estimated $25 million for the near-term work, $100 million for the midterm, large-scale equipment, because it takes anywhere from $100 to $500 million at pilot scale to prove some of that technology so that it is commercial, and $25 million on a sustaining basis for the advanced research activity.

I believe support in all three areas is necessary, but if you want to be effective, it has to be a stable, sustained program. There has to be some fiscal assurance to attract the best people and the best companies to carry out the research and development.

I thank you very much for this opportunity to express my opinion.

[The prepared statement of Dr. White follows:]

STATEMENT OF PROF. DAVID C. WHITE, ENERGY LABORATORY, MASSACHUSETTS INSTITUTE OF TECHNOLOGY, CAMBRIDGE, MASS.

Coal: The Problem in Technology and Markets

The fact that the House Committee on Science and Technology is holding this meeting on the adequacy of government's role in supporting coal research is a sign that the Committee members appreciate the enormous importance of U.S. coal resources in the country's present and long-term energy program. I hope my testimony will help to reinforce that appreciation.

As we all know, coal has been used as a source of both heat and chemicals for well over a century. Commercial processes and systems exist for mining, transporting, and burning coal. In fact, over 50% of the total electricity used in the U.S. is derived from coal-fired boilers. For this admittedly mature and commercial industry, what coal research and development is needed and why should government financial support be considered?

In my view, there are three categories of coal R&D that are needed. The near- and mid-term developmental needs are a result of changing energy prices in the last decade and society's desire for an environment reasonably free of contaminants. The longer-term research is required to make the most effective use of our vast coal resources for future generations.

Item 1: Near-Term Technology Improvements

Improved technology in coal beneficiation and combustion control to use coal more effectively and as an alternative to fuel oil in existing coal- and oil-fired boilers.

Item 2: Mid-Term New Coal Technology Development

New utility-scale coal combustion techology having improved efficiency and reduced environmental emissions that is capable of operating using a wide range of coal quality.

Item 3: Long-Term Coal Research

Advanced research on coal's structure, chemistry, and combustion and on chemical pathways for liquefying and gasifying coal.

If this is a reasonable R&D program, why should government be involved? Coal is now being used commercially; why can't coal users and equipment suppliers make the needed improvements and continue to exploit this abundant fossil fuel in a way that meets society's demands? With petroleum selling at two to three times the delivered price of coal, and natural gas not far behind, what's the problem?

Over the next two decades coal will be used to produce industrial steam and--to a limited extent--to make synthetic fuel. But the main market by far will remain the electric utilities. One might then argue that the first two items--upgrading coal and improving existing combustors, and developing new combustion systems--should be accomplished by those with a vested interest, namely, the electric utilities and the companies that manufacture equipment for them.

Unfortunately, while the societal pressure for improved technology is strong, the economic incentives within the industry are not. The problem is that the industry is regulated: both federal and state regulatory bodies are given responsibility for dealing with the complex issues of social equity for consumers and for decreeing fair rates of return for utilities.

The potential impact of new coal technology on utility costs is not clear. Use of a new technology should improve plant operations, make plants more reliable, and reduce environmental emissions. It may also increase the range of coal quality that a utility can burn. Some of these factors lower operating costs; others raise operating costs but reduce emissions. The capital costs of new technology appear to be equal to or greater than those of existing commercial technology, and the risk associated with introducing new large-scale technology is always high. If any reduction in operating costs could be captured by the utilities, the gains might offset the risk. However, the regulatory process ensures that this won't happen. For the utility, then, the allowed choice is to take the risk without capturing the gain--a typical and well-known failing of regulated markets(1).

The problem is compounded by rising energy costs and the consequent leveling off of electricity demand in many parts of the nation. The utilities have massive capital equipment in place; given their current financial troubles, there is a clear economic advantage in using that equipment as long as possible. Needless to say, equipment manufacturers are not strongly motivated to develop improved new systems when they have no buyers. Therefore, many utilities continue to use existing coal-fired boilers without extensive emissions controls, and some use equipment fired by expensive residual oil. There are few, if any, market incentives for utilities to search for ways of reducing emissions in existing coal-fired plants; and there are actually disincentives to converting oil-fired systems to coal.

Past government mandates to force retrofitting and to encourage introduction of new technology have been ineffective. One cannot mandate the introduction of noncommercial technology. The real benefits of retrofitting and introducing new coal technology will be reaped by society in the form of lower emissions and lower costs. It appears, therefore, that government is both the source of market constraint and the recipient of any social gains from the use of new or better technology. Thus, the government must take a major role in supporting or at least stimulating the necessary research and development.

The third item--advanced research on the structure, chemistry, and combustion of coal--will produce results that, in the near term, could prove extremely helpful in our attempts to develop new and improved combustion systems. Far more important, though, are the longer-term results of that work. In the next century, the ability to upgrade the world's coal reserves into higher-grade hydrocarbon products and chemicals may be as important as manipulating the genes of plants or producing improved integrated electronic circuits for computation and communication. Developing a better understanding of coal and its behavior should help us identify novel methods of gasifying and liquefying coal.

The results of today's advanced coal research will ultimately have a commercial payoff. However, that payoff is so tenuous and--at best--far in the future that today's industry cannot be expected to support more than a limited part of the work. Therefore, the government must categorize advanced coal research as "fundamental" and fulfill its standard duty of providing financial support.

R&D Choices

Before tackling the funding question, let me briefly describe each of the three technical areas that I introduced above.

Item 1: Improved technology for existing coal- and oil-fired boilers.

Burning coal more effectively in existing coal-fired boilers and substituting it in oil-fired boilers have significant benefits.

Today, there is growing interest in physical coal cleaning to remove ash and other inorganic contaminants. Modest cleaning methods to reduce ash and pyritic sulfur for pulverized coal-fired boilers are now in use. The Electric Power Research Institute (EPRI) has established a coal-cleaning research facility at Homer City, Pennsylvania, and research there should develop improved coal cleaning technology that will benefit all coal-using utilities. To be commercially feasible, more severe coal cleaning methods require improvements in fine grinding to reduce energy requirements and development of large-scale de-ashing technology that is practical and cost-effective. The potential gains from more severe physical cleaning need further evaluation.

A second part of a program to improve coal combustion involves developing advanced control systems that would monitor emissions and maintain optimum combustion conditions. Developing such systems requires understanding the complex physical and chemical reactions that occur in a large-scale combustion system. This includes ash characterization and reaction product formation as influenced by operating conditions.

Physically cleaning coal and using advanced control methods on combustors involve using existing technology and science in new ways. Yet these approaches have received limited attention in the past decade because people thought that existing technology was adequate and that the best route to any improvement was via synfuels. However, synfuels are not now economically viable for producing a boiler fuel, and they probably won't be in this century. More effective use of known coal science and engineering to develop improved processes is required if we are to use our most abundant, cheapest fuel in existing equipment while addressing today's environmental concerns.

Item II. New technology for coal combustion.

Current science and engineering activities focusing on coal have shown that it is possible to develop cleaner and more efficient systems for new utility plants. However, establishing a commercial process remains complex and expensive.

Several new types of combustion technology appear promising. The atmospheric fluidized bed promises significantly decreased emissions: it operates at lower temperatures than a conventional combustor, so it produces less nitrogen oxides; and it incorporates chemical sorbents that reduce emissions of sulfur oxides. One version of the technology--the bubbling bed--has received government support and is now commercial in small sizes. To be useful in a utility, systems must be at least an order of magnitude larger--an increase in size that introduces many new problems. The Tennessee Valley Authority (TVA) and EPRI are now working on a utility-scale bubbling bed. The 20-MW prototype to yield design data for the desired 200-MW system will cost $70 million. Other configurations of atmospheric fluidized beds using fast fluidization and solids recirculation may be more adaptable to utility-scale systems. Pilot plant evaluation of these systems is not currently being supported.

Two other approaches under study offer the efficiency advantages of combined cycle systems. The International Energy Agency (the U.S., Great Britain, and West Germany) is now developing a pressurized fluidized bed, which could be used in gas turbine-combined cycle applications. Another approach uses partial oxidation entrained flow or fluidized bed gasifiers to supply a gas turbine-combined cycle system. EPRI and several utilities and industrial companies are funding a pilot plant unit of one type of gasifier-combined cycle system at Cool Water near Barstow, California (300 MW thermal). This pilot plant is costing $300 million, and the project almost failed to get the necessary funds. Although the utility industry is interested in such new coal technologies, it continues to have difficulty raising adequate funding to bring them to commercial scale.

Area III. Advanced research on coal chemistry and combustion.

Today, we tend to use three general methods of processing coal: thermal decomposition (pyrolysis); hydrogenation from a gas phase or donor solvents; and thermal decomposition to carbon monoxide-hydrogen mixtures with catalytic resynthesis to new hydrocarbon structures. All of these methods are fairly well understood, and commercial or pre-commercial processes have been developed.

These technologies are based on research done by German chemists in the 1930s and 1940s. Their work was clearly outstanding; but with all the advances in organic chemistry of the last fifty years, surely we should be able to develop a better understanding of coal's structure and chemistry than they had to work with. That fundamental understanding would make possible improvements both in coal combustion and in methods of gasifying and liquefying coal.

It appears that coal has not yet been fully accepted as a substance worthy of advanced scientific research. Sophisticated tools of analysis have been used to investigate coal structure and chemistry, but only to a limited degree. Our basic understanding of coal structure and the chemical pathways for modifying and subdividing the hydrocarbon substrates therein is still in its infancy, with an enormous potential for both scientific exploration and technological applications. The contributions possible from fundamental organic chemistry using the advanced analytical tools of spectroscopy, especially infrared and nuclear magnetic resonance, electron and X-ray microscopy, chromatography and neutron activation analysis, will yield much important quantitative structural data. This information, used in conjunction with modern quantum-chemical theories such as frontier orbital interactions and sophisticated kinetic and stereochemical experiments using coal model compounds, may help identify pathways for coal modifications that could lead to more efficient practical processes at lower temperatures and pressures with much higher efficiency and less hydrogen consumption.(2,3) Our leading geneticists are making tremendous strides in modifying the complex genetic materials DNA and RNA; coal should be no less penetrable to our leading chemical scientists.

Institutional Arrangements

Items I and II.

Improving coal use in existing equipment (Item I) and developing new utility-scale commercial coal-burning equipment (Item II) both require the participation of utilities and their suppliers of equipment. However, as stated previously, the current climate of regulation and financial stress is hardly conducive to investment in R&D. The utilities may be able to make relatively small investments in an attempt to improve their existing combustors. But making major improvements or, especially, developing new combustion technology that will satisfy society's demands is an expensive proposition. There must be extensive testing in a small experiment unit followed by construction of a pilot-scale facility and finally commercial-scale testing of operational characteristics, reliability, and costs. The total cost far exceeds that which any single equipment manufacturer or utility can risk, especially when the potential payoff is limited.

Recognizing that problem, ten years ago the utilities jointly established EPRI to share the costs and risks of R&D programs. The resulting programs have effectively brought the utilities and their suppliers into cooperative development activities; and in past and some current programs, there has been joint funding from industry, EPRI, and DOE. Recent decreases in DOE's funds for fossil energy R&D have significantly reduced available joint funding, so EPRI has been forced to focus most of its funds on near-term projects. Even so, there is not sufficient funding to maintain a "socially optimum" program.

Coal technology is almost as complex as nuclear technology is, so coal R&D requires the same attention and commitment that nuclear R&D is now getting. Thus, improving existing equipment and developing new coal-using systems that meet today's environmental goals require sustained funding at high levels. EPRI's 1982 budget(4) is $250 million, of which $90 million is for improved or new coal technology. Thus, EPRI, the utilities, and the equipment suppliers do have a program under way, but it is too small and too focused on near-term projects to bring forth a reasonable set of competing technologies in a timely fashion. Government support is needed to accelerate the R&D process.

In the past, government has generally identified technologies it deemed important and given money to industry and national laboratories to develop them. A more effective method might be to allocate money through EPRI, perhaps by providing matching funds for EPRI/utility programs--an approach that could make a good but limited program more comprehensive and timely.

The involvement of EPRI provides several advantages. For one thing, the EPRI organization maintains close ties with utilities nationwide. Thus, it is familiar with the needs, problems, and limitations of utilities operating in various environments; and it can ensure that technology advances are communicated to potential users and adopted where economically viable. EPRI also involves international companies, so U.S. researchers participating in the program could find out about any foreign developments upon which their research could build.

In the past, U.S. companies were leaders in combustion technology. Foreign equipment suppliers have now passed them by. A federally supported program involving utilities and equipment suppliers and operated through EPRI could help the U.S. regain its leadership role in coal combustion technology.

Item III.

The advanced coal research described previously is fundamental in nature; but unlike "pure" fundamental research, this work has a goal--one that is of the utmost commercial importance. Therefore, the advanced research must be closely coupled with applied research and development activities. This coupling requires creative institutional arrangements. One good approach would be to create (or expand) a limited number of centers of excellence in coal science and technology. Each center would perform both fundamental and applied research and would involve a range of personnel, including creative young people. An advisory board of representatives from the utility industry and equipment supply companies would provide knowledge and experience, ensuring that the research is responsive to the needs and limitations of the mature, functioning industry. Exchange of information and--when possible--of personnel should be encouraged.

In the 1940s and 1950s, centers of excellence focusing on high-energy physics were established, and some of them continue to function today. More recent efforts to create such centers haven't been so successful. DOE tried to set up university coal research laboratories, and DOT tried to create the Cooperative Automotive Research Program. Neither program was implemented. Vested interests by regions, government, universities, and industry seemed to override and sidetrack the best-conceived plans.

One example of a highly successful multidisciplinary program is the Center for Health Effects of Fossil Fuel Utilization, which was established by M.I.T. with support from the National Institutes of Health. This creative program encompasses work spanning from fundamental science through engineering applications; and it brings together toxicologists, applied biologists, chemists, and combustion scientists and engineers into new working arrangements. At the outset, NIH awarded long-term (five year), multimillion dollar support and adopted an effective review procedure to ensure that the research continues to be of the highest quality. The vision and commitment of NIH are already paying off, as scientists and engineers working cooperatively through the Center are now producing valuable research results.

There is now a crucial need for a few such centers of excellence in coal chemistry and combustion--centers that receive multi-year funding at a high level for researchers ranging from scientists doing fundamental research to engineers looking at potential industrial applications. Existing dispersed, short-term, low-level funding has not created an effective coal science program; and the drastically reduced funds for coal research proposed by the Administration for 1983 continue to neglect that need. It is time for a new institutional approach and a serious financial commitment from the federal government.

Funding Recommendations

Recommending a specific research program and an appropriate level of government support is difficult. In some instances, it is easier to suggest what not to do than it is to design a viable program. Past coal programs have been dominated by the vested interests of states with large coal reserves and by the appeal of a simplistic technology fix. A broader, more far-sighted approach is crucial.

The current DOE-funded activities most nearly related to the R&D I recommend for enhanced support are:

	1983 proposed by DOE
Coal technology and coal beneficiation	$ 9 million
Combustion systems	$ 6 million
Advanced research and technology development	$20 million

These three programs total $35 million out of $91 million proposed by DOE for coal R&D.

I believe that a budget of five to ten times the proposed $35 million could be used effectively. I suggest the following for consideration:

Item I:	Improved coal beneficiation and combustion for existing boilers	$ 25 million
Item II:	New combustion technology	$100 million
Item III:	Advanced coal research	$ 25 million

If I were required to set priorities for these research areas, I would place them in reverse numerical order: Item III, then Item II, and finally Item I. The highest priority, though, is that the funding be stable: whatever program is established must be sustained for many years to be effective. The quick-fix, roller-coaster mentality that has permeated past and current DOE R&D planning is a sure and proved way to waste money. While I cannot provide hard programmatic data to justify the support levels indicated above, I believe they are the minimum levels that can bring forth the new and improved technology that will allow us to use coal in a manner consistent with the societal goals of the 1980s and beyond.

References

1. *Technology Change in Regulated Industries*, W. M. Coupon, Ed., The Brookings Institution, Washington, D.C., 1970.

2. *Assessment of Long-Term Research Needs for Coal-Liquefaction Technologies* (FERWG-11), S. S. Penner, Chairman, March 1980, DOE/Office of Energy Research and Fossil Energy.

3. *Pathways in Coal Thermolysis: A Theoretical and Experimental Study of Model Compounds*, M.I.T. D.Sc. Thesis, January 15, 1982, Ini A. Ekpenyong, Prof. P. S. Virk, Supervisor.

4. Electric Power Research Institute 1982-1986 Research and Development Program Plan.

Appendix A

Coal-Related R&D at the M.I.T. Energy Laboratory

When the M.I.T. Energy Laboratory was formed in November 1972, one of its major thrusts was to perform research on the clean and effective use of contaminated fossil fuels (coal, shale, and heavy petroleum). Since then, faculty and students from the departments of Chemical Engineering, Mechanical Engineering, Materials Science and Engineering, Aeronautics and Astronautics, Civil Engineering, Chemistry, and Nutrition and Food Science (including applied biology and toxicology) have been working with Energy Laboratory staff on a broad program of advanced and applied coal research.

Energy Laboratory researchers are identifying specific emissions from existing coal combustors, determining whether they are harmful to human health, and relating their health impacts to fuels and combustion methods. We are also studying the effects of coal use on the environment and are developing ways to predict, monitor, and control those effects. We are developing methods of processing coal to remove pollutants and to convert it to forms usable in a wide range of combustion systems. We are looking at changes in the design and operating techniques of our existing combustion equipment that will enable that equipment to burn coal more safely and efficiently. Finally, we are creating devices that clean pollutants from the exhaust from coal combustors, and we are developing entirely new technologies that use coal efficiently without adverse environmental or health effects.

This work requires extensive laboratory equipment. Decades of coal-related research have produced many facilities in department laboratories, and those facilities have been supplemented by new Energy Laboratory construction. The most important facility built by the Laboratory is the Combustion Research Facility (CRF). Constructed between 1977 and 1979 at a cost of $1.5 million, the CRF permits detailed experimental studies of industrial-type burner flames of gaseous, liquid, and solid fuels. Its key components is a calorimetrically cooled experimental combustion tunnel that is 1.2 by 1.2 meters in cross section and 10 meters long and has a maximum heat input of 3 megawatts. Combined with results of small-scale laboratory tests on combustion chemistry and kinetics, data gathered in the CRF are providing utilities and other coal users with new information on nitrogen oxides reduction, the chemical and physical characteristics of ash, the kinetics of submicron particulate formation, flame conditions that lead to pollutant formation, and many other important topics.

To illustrate the extent of our commitment to coal research, I list below the specific titles of some of our coal-related projects. (Further descriptions of these projects can be found in Project Summaries, July 1, 1981, to June 30, 1982, available from Energy Laboratory Headquarters, M.I.T. Room E40-454, Cambridge, MA 02139, (617) 253-3400.) In FY '82 the Laboratory spent almost $5 million on these activities--nearly half the Laboratory's total budget for that year. This commitment indicates our belief in the significant role coal must play in the nation's energy future and the importance of training the kinds of scientists and technologists that the industry will need.

Coal-Related Activities at the M.I.T. Energy Laboratory, FY '82

STATIONARY COMBUSTION

Combustion Research Facility

Development of a Design Strategy for the Combustion of Coal-Derived Liquid Fuels

Combustion, Heat Transfer, Ash Deposit, and Pollutant Emission Characteristics of Coal-Oil Mixtures (COMs)

Determination of the Heat Transfer, Ash Deposition and Pollutant Emission Characteristics of Concentrated Coal-Water Slurries (CWS)

Combustion Studies of Particulates

Source Book of System Design Data for Fluidized Bed Combustors

Pressurized Fluid Bed Combustor

Freeboard Reactions in Fluidized Coal Combustion

Experimental Studies for Testing of Models and for Scale Up of Fluidized Bed Combustion

Modeling of Fluidized Bed Combustion of Coal

Combustion Modeling

Influence of Bed Fluid Dynamics on Heat Transfer to Surfaces Immersed in a Fluidized Bed: Scale Up, Particle Shape, and Particle Size Distribution

Fiber Optic Sensor for Fluidized Bed Behavior Measurement

Reactions of Fixed Nitrogen Species Under Sooting Conditions

Oxygen Deficient Conditions

CaO-Acid Gas Reactions

CaO-C Reactions

Diffusion in Char Gasification and Combustion

Char Gasification

Relationship of Flame Hydrocarbon Intermediates to Surface Deposits and Hydrocarbon Emissions

Characterization of Mixing by Products from Competitive Reactions

Growth of Submicron Particles

Fundamental Combustion Research Applied to Pollution Control: Hydrcarbon Combustion

Reduction of Pollutant Formation in Coal Particle and Liquid Spray Flames

Combustion - Coal Heavy Liquid

Macroscopic Models for Electrically Augmented Filtration of Fine Particles Entrained in High Temperature Gases

A-C Electrostatic Precipitator Development for Filtration of Highly Resistive Ash

Electrofluidized Beds

Fundamental Studies of the Physico-Chemical Properties of Coal Slags

REACTIONS AND HEALTH EFFECTS OF POLLUTANTS

Toxicology of Inorganic Coal Combustion Aerosols: Thermochemistry of Inorganic Combustion Particulates

Toxicology of Inorganic Coal Combustion Aerosols: Generation and Characterization of the Inorganic Aerosols Produced During Coal Combustion

Toxicology of Inorganic Combustion Aerosols: Aerosol Characterization Laboratory

Toxicology of Inorganic Combustion Aerosols: Pathological Studies -- Morphologic Evaluation of Acute and Subacute Effects of Respiratory Toxicants

Toxicological and Chemical Interactions

Toxicology of Inorganic Combustion Aerosols

Toxicology of Inorganic Combustion Aerosols: Toxicological Assessment, Pulmonary Function

Toxicological and Chemical Interactions of Metal Oxides and Sulfur Dioxide

Basic Studies of Organic Particulates from Vaporizable Fuel Combustion

Monitoring Combustion Products by Laser Spectroscopy

Toxicology of Fluoranthene

Health Effects of Combustion-Generated Soot and Polycyclic Aromatic Hydrocarbons

Chemical Analysis Facility

Air Quality Modeling Validity and Uncertainties

Evaluation of Health Effects of Air Pollution in the Chestnut Ridge Area

Acid Rain: Analytical Methods for Gases

Acid Deposition in a Massachusetts Water Supply Watershed: The Roles of Biological and Abiotic Buffering on the Bickford Reservoir and Watershed

ENERGY CONVERSION

Key Contributions in MHD Power Generation

SYNTHETIC FUELS

Critical Studies in the Rapid Pyrolysis and Hydropyrolysis of Coal

Coal Pyrolysis by Hot Solids from a Fluidized Bed Combustor

Fundamental Studies of Heat Transmission in the Coal-to-Coke Transformation

Coal Gasification and Tar Conversion Reactions Over Calcium Oxide

Thermal Reactions of Aromatics in the Presence of Calcium Oxide and Their Application to Upgrading Coal-Derived Liquids

Fischer-Tropsch Synthesis in Slurry Reactor Systems

Liquefaction Research

Studies of Fluidized Bed Combustion of Spent Oil Shale and Coal

PROCESS MODELING

Advanced System for Process Engineering (ASPEN)

Transferring ASPEN Technology to Morgantown Energy Technology Center

APPENDIX B

PROFESSOR DAVID C. WHITE
Ford Professor of Engineering
Director, Energy Laboratory
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Prof. David C. White is Ford Professor of Engineering and Director of the Energy Laboratory at the Massachusetts Institute of Technology. As founding director of the Laboratory in 1972, he has been involved in its growth into the largest interdisciplinary research laboratory at M.I.T. The energy-related research done at the Laboratory covers a broad range and includes: supply and utilization technology, environmental and health sciences, economic analysis and regulation, R&D planning, and policy analysis. Prof. White's own fields of research are energy system planning and analysis, electric power systems, and R&D planning for energy technology and policy.

Prof. White attended Stanford University where he received the B.S., M.S., and Ph.D. in Electrical Engineering in the years 1946, 1947, and 1949 respectively. He was a fellowship student at Stanford University from 1946 through 1949, then joined the faculty of the University of Florida as an Associate Professor from 1949 to 1952. In 1952 he was appointed to the Faculty of Electrical Engineering at the Massachusetts Institute of Technology as an Assistant Professor, was promoted to Associate Professor in 1954, Professor of Electrical Engineering in 1958, Ford Professor of Engineering in 1962 and Director of the Energy Laboratory in 1972. His publications include a number of articles in professional journals and the textbook Electromechanical Energy Conversion (Wiley, 1958).

Prof. White is a member of the National Academy of Engineering, the American Society for Engineering Education, the Institute of Electrical and Electronics Engineers (Fellow), the American Academy of Arts and Sciences (Fellow), and the Honorary Societies Phi Beta Kappa, Sigma Xi, Tau Beta Pi, and Eta Kappa Nu.

Prof. White was an invited lecturer on Energy Conversion at the University of London in January 1961. He was the 1961 recipient of the George Westinghouse Award of the American Society for Engineering Education for his contributions to Energy Conversion. He was an Honorary Professor at the Instituto Politécnico Nacional, Mexico, Visiting Professor at the University of Wisconsin in 1962, part-time Visiting Professor at Purdue University from 1963-1967, and Visiting Professor and Senior Advisor, Birla Institute of Technology, Rajasthan, India, from 1968 to 1970. He was a Member of Council, University of Benin, Nigeria, April 1972. He was a Trustee of Lowell Technological Institute from 1972-1974. He is a Member of the Corporation, Woods Hole Oceanographic Institution and is on the Research Coordination Panel of the Gas Research Institute (presently Chairman of the Panel, 1981-1983). He is on the Advisory Council of the Electric Power Research Institute (presently Vice Chairman, 1982-1984). He is a member of the Committee on Energy and Environment of the National Association of State Universities and Land-Grant Colleges and was on the Liaison Subcommittee on Energy Systems of the Advisory Committee on the International Institute for Applied Systems Analysis from 1977 to 1982. He was a member of the Visiting Committee of the Energy Research Center of LeHigh University from 1979-1982. He is a consultant and energy advisor to several industrial firms.

9/1/82

Dr. Wolfe.

Dr. WOLFE. Mr. Chairman, it is my pleasure to come here directly from the coal fields of southwestern Virginia. I know this is the last of your testimony hearings, but I would like very much to give you a perspective that you probably have not heard yet, a perspective from one whose father was a coal miner, who was brought up in the little coal mining town of Sophia, W. Va., which is the hometown of our most distinguished U.S. Senator from West Virginia, Robert Byrd, but also a perspective from one who has worked in the nuclear program for a number of years, and the space program, and who was also a Federal employee here in Washington for 5 years in both the nuclear and the coal programs.

I have now for the last 3 years been directing one of the largest research and development programs for a coal company in the United States, and we have been making some great progress, but I am disarmed and very concerned by the Federal budget I see today for coal research. I think that we must cut back on Federal spending, but we must cut it back wisely and we must spend those dollars that we have available to us wisely.

I just met yesterday at Germantown with some of the people I used to work with in the nuclear programs. I absolutely—it is almost criminal to look at the budget that they are spending for nuclear research and development.

Now I know that your committee does not address that issue completely, but if we are going to cut back Federal spending, then for God's sake, let's cut back in a balanced way and look at our national perspective.

I don't think that we can afford to play politics with our nuclear and coal research and development budget. We need them both, but they have to be done in a balanced way.

I have looked over the coal budget for the last several years, and the budget that you have responsibility for, and I have a few suggestions about where the emphasis should be placed. I do think that if we have a limited budget, then we have to use it wisely.

First of all, there is a new technology that is being developed called liquid coal; that is, to convert coal into a liquid form so that it can be pumped and transported, burned, just like you would oil.

If we can develop that technology, then we can immediately increase the coal market for coal about 70 million tons. Today we are still importing 4 to 5 million barrels of oil every day. The utilities along this coast are still burning oil every day.

There have been very few utilities that have converted back to coal. In fact, it is almost folly to talk of the utilities who were on the hitlist of the Government to convert back to coal, and then you ask them why haven't you converted back to coal, even though at one time you did burn coal.

There are several reasons for that, one being that they can pass the rate on to their ratepayers and you have taken the incentive away by the Fuel Adjustment Act. Second, it is convenient fuel. They don't have to shovel it, they don't have to put it on belt lines.

So, if that is the case, why can't we develop coal into a liquid form? We can. It is nothing more than just grinding the coal up into a very fine powder and mixing with water or oil and mixing it with a new chemical technology, surfactants, and making a stabilized solution.

We are doing that as part of our own company R&D, but the impetus has to come from the Federal program. I think if you look at the current DOE budget and see where the best priority should be placed, I think you can have an immediate impact upon the industry, upon the Nation, by developing a liquid form of coal.

Second, I think we have to concentrate in the area of beneficiation. That is an area that directly affects the coal industry. Technology is 30 years behind the times, and by spending more effort in the area of how you reduce the sulfur and reduce the ash from the coal before it is burned, you have then solved the problem rather than spending a lot of money upon the off-gas cleanup systems. The off-gas cleanup system is a little bit like letting the horse out of the barn. It is better to try to correct it before it ever gets out.

I think in those two areas, if you can just look at your coal R&D budget you have before you, and concentrate upon what is going to be of immediate benefit—it is long range, it is high risk, no question about that, because with the coal industry you don't have to look very far to find things that are high risk and long range—so let's concentrate on spending the dollars that we have, and let's spend them wisely.

I think that in the area of fluidized bed combustion of coal waste we have something like 900 million tons of coal waste in this country piled up on every ravine, every mountain that you can go through West Virginia and Virginia, and that coal waste has something on the other of 6,000 to 10,000 Btu's per pound in value. It is sitting there, and some of it is causing environmental problems.

Fluidized bed combustion is one combustion technique that does have the capability to burn that low-grade fuel. I definitely think that the R&D budget should be looked at to stimulate that area.

With regard to coal mining, there has been a tremendous amount of dollar spent by the Federal Government in the area of coal mining. I believe as a result of those dollars we now have an advanced state of coal mining. I think you can directly relate it back to Government spending over the past few years.

We can mine more coal today than we can use or sell, so I believe that you can back off some of that for the time being and spend the money in the area of beneficiation or coal utilization and let the continuous miners and the technology that exists today do its job.

Those are a few suggestions I have for the coal budget. I really can't make those suggestions without having you recognize the responsibility that you have as Congressmen to look at the total DOE budget.

I do and am appalled at the fact that the nuclear budget seems to be coming out as a very pro-Republican Party budget and the coal program a Democratic Party budget. We can't have that in this Nation. We need them both.

The big villain we have is imported oil. That imported oil cost our country $70 billion last year. It is draining our economy. If you look at the national budget deficit, it is about $70 billion.

If we could turn that money back around and start converting coal to gasoline or converting coal in utilities, we can start putting that money to work in this country. I think it is your responsibility, even though it is outside the scope of this subcommittee, to influence the total DOE budget to look at a balance.

I don't think it should be an increase. I think we have to cut back on all Federal spending. But let's look at the balance of what this Nation really needs.

We need two forms of energy: electricity and gasoline. You can't make gasoline from nuclear power. Therefore, you need to look at those programs that can help us get out of this mess that we are in with this imported oil. It is draining our country, the economy. If we can turn that around, that is the biggest impact we have had to set ourselves on energy independence.

Thank you very much for this opportunity.

[The prepared statement of Dr. Wolfe follows:]

Dr. Richard A. Wolfe
Vice President, Research and Development
United Coal Company
Bristol, Virginia

Mr. Chairman and distinguished members of the subcommittee, I am Dick Wolfe, Vice President of Research and Development with United Coal Company. It is my pleasure to have this opportunity to address this subcommittee.

Your subcommittee is in its final phase of hearings and you have already heard from many different people with many different perspectives. And I want to give you yet another perspective. A perspective you have not yet heard and one that will hopefully make a lasting impact on the direction of federally sponsored coal research and development.

This perspective comes from being the son of a West Virginia coal miner and one whose father died from Black Lung disease; a perspective from one raised and reared in the coalfields near Sophia, West Virginia (which, by the way, is also the hometown of U. S. Senator Robert C. Byrd), a perspective from one who was employed in the U. S. nuclear weapons and space programs for 13 years, a perspective from one who worked as a federal employee for 5 years here in Washington, D. C. with the Atomic Energy Commission, the U. S. Energy Research and Development Administration and the Department of Energy; a perspective from a member of the Virginia Coal & Energy Commission and a perspective from one now directing the Research & Development Department of the largest privately owned coal company in the United States.

My objective here today is to give you specifics about the good and bad of the current federally sponsored coal research programs and where the program emphasis should be placed. I plan to cover two topics with the emphasis being placed first on your immediate concern as to what the coal budget should be and the types of projects to be funded; and secondly, discuss the broader topic of the U. S. energy perspective and how the priorities of the total federal DOE budget should be balanced.

Need for Federally Sponsored Coal Research and Development

After being a federal employee in Washington and witnessing firsthand the waste of taxpayers' dollars on misdirected programs, I totally agree with the need to drastically cut federal spending. This opinion applies as well to the Department of Energy's programs. The DOE, as initially conceived, started projects on all phases of energy-related activities without a clear direction of priorities and needs. With the drastic cutbacks in federal dollars, it is now more important than ever that the federal dollar be spent wisely to achieve the maximum objective.

There has been a drastic change in the government-funded coal program during the last year (FY 82) and in the formulation of FY 83. To us in the industry, we are distressed and concerned at the wide arc and short period of the recent change in the Administration's policy. It is not clear if there is a focus in the resulting program or perhaps the focus is one to create disorder.

There is a much overworked and probably not understood phrase, "long term, high risk and proof-of-principle." While these words are used, it is difficult to interpret their meaning or relate then to the funded work. It appears that the fossil program funds a full gamut of R & D in technologies that range from those that are near maturity and are associated with well-established industries to those that cannot possibly impact this nation for 30 to 40 years. These latter technologies can be viewed well beyond the horizon of any planning both by the private sector and by the government.

The government funded coal R & D program must address the entire coal fuel cycle. Clear delineation of the objectives of the coal program needs to be articulated in terms of goals and time frame, and reflect the attitudes and idiosyncrasies of the industry that must in some time period bring new technologies to the marketplace. These objectives must be coupled to the commercialization process and the programs developed/defined/scrutinized as having value to the nation. We think it folly to justify R & D efforts as "long term, high risk proof-of-principle" without this coupling.

Given that one prime objective is the increased use of coal and reduction of importation of oil, the resulting program must have developed from specific system targets that are real and with use of government funds will have high probability of success.

The actual execution of the major program thrusts should be performed in concert with those industries who will, through government participation, establish proof-of-concept and mitigate the high-risk aspect of new ventures. United Coal Company endorses and supports cooperative ventures. We have had far too much growth in the "Beltway Bandits" who thrive and live totally off the federal dollar. Consequently, by encouraging coal companies such as ours to participate directly with the government in the development of technology, then the transfer of those technologies is already in the marketplace.

Coal Research and Development Projects. Based upon the groundwork now laid in the philosophy above, let me give you some specifics on those coal R & D projects now "earmarked" for funding by the federal government.

1. Coal Utilization Directed Towards Creating New Coal Markets

Liquid Coal Type Projects - Converting coal to a liquid form (coal-water, coal-oil, coal-methanol, or other combinations) will make coal a convenient fuel that can be transported, stored, and burned to replace oil. This phase of the DOE's program has tremendous potential benefits for creating an expanded use for coal as a direct replacement in those utilities and industrial boilers now burning oil. Pump out the oil and pump in the liquid coal. Approximately 70 million additional tons of coal could be used in this liquid form by replacing oil now being burned. The area of liquid coal combustion, transportation and beneficiation of the coal to very low levels of ash and sulfur comparable to that of oil should receive increased funding.

Gas Turbine Projects - These types of projects offer some of the greatest benefits to future electricity generation at lower cost, greater efficiency, and improved environmental control. Significant technology advancements have been made recently in this area and additional R & D needs to be provided to bring these technologies to a commercial feasibility. In addition, the coupling of the low ash and sulfur liquid coal concept with the gas turbine makes for a low cost, new power generation concept.

Fluidized-Bed Combustion of Bituminous Coal Waste. Coal waste from preparation plants represents a coal resource of approximately 900 million tons of recoverable coal. Much of this coal waste can be directly fired in a fluidized-bed system. This coal resource is so great that we must develop ways to utilize it for power generation. In addition, once the coal waste has been burned, the resulting spent fuel is far more environmentally acceptable than the coal waste. Past government R & D has already produced the impetus for this technology. Continued R & D funds are needed to bring about fluidized-bed's greatest asset of burning coal waste from preparation plants.

Liquefaction of Coal - It appears that an inordinate 25 percent of the coal budget is directed at liquefaction. While we all recognize the importance of liquids to our national well being, we are concerned that a serious imbalance exists. Industry is already moving ahead with the state-of-the-art gasification technology (Tennessee Eastman's commercial plant in nearby Tennessee).

Let's spend our federal dollars to bring about the commercialization of one or two large plants using today's technology rather than spending a lot of federal dollars studying anticipated problems before we ever get the ship afloat. It is a matter of immediate priorities and budget limitations and, therefore, the funding here should be reduced in favor of more immediate programs.

Direct Combustion and Off-Gas Clean-Up - There is considerable work in direct pulverized coal combustion, yet this is a technology well understood by the private sector. We work with these companies and are impressed with their knowledge and ability to develop the needed systems. Many of them have techniques for reducing NOx and have pursued in situ sulfur capture and advanced scrubber design. Technology to beneficiate the coal of its sulfur and ash at the coal mine is the best and by far the most economical method to minimize off-gas pollutants. Again, let's first spend our limited federal dollars on coal beneficiation technology and reduce efforts to improve methods to "catch the horse after it's out of the barn."

2. Coal Beneficiation to Remove Sulfur and Ash

Eighty percent of all Eastern coal mined today requires beneficiation in the form of ash and sulfur removal. However, the technology being used today is some 30 years old. Few, if any, new breakthroughs have been developed in recent years to improve the efficiency of ash and sulfur removal of coal recovery. In the past, only a small portion of the coal R & D budget has been allocated to this area of the coal fuel cycle. If we ever expect to replace oil in utility and industrial boilder and produce quality synfuels, then we must develop the technology to reduce ash and sulfur down to those levels to minimize the need for expensive off-gas clean-up systems.

3. Coal Mining

Currently, the technology to rapidly remove coal from the ground has certainly outpaced its demand. Technology in this area is sufficient to meet the next 10 years' demand, therefore, less federal money should be spent in this area. It is interesting that this is the area which has received most of the federal R & D dollars in the past. Mining technology is at an advanced state compared to the other areas because of those funds. However, one area should be supported and that is for the development of mining techniques to reduce coal dust generation.

In summary, these are a few of the changes recommended for the current coal R & D program. Profoundly and just as strongly as I can say it, I believe the federal DOE funded coal budget should be substantially increased beyond current levels. What has been most disturbing to me in the Department of Energy's budget for 1982, 1983 and that contemplated for 1984 is that there has not been a unilateral cutback in the various energy programs but rather a build-up in the nuclear R & D programs at the expense of coal and other alternative energy programs. Gentlemen, this misalignment of federal DOE funds is blotted with politics. The coal program cannot and should not be just a Democratic Party program and the nuclear program a Republican Party program. God knows, we need them both if we are to defeat the "Import Oil Villain." It doesn't make sense to reduce the coal R & D program by more than 50% when that energy source provides nearly 20% of our energy needs and increase the nuclear program by more than 50%. Where are our national energy priorities? Much of the nuclear funding is hidden deep within the budget under defense programs so one doesn't even know how much nuclear R & D is really funded. The $3.5 billion Clinch River breeder reactor is just one of the more visible nuclear projects that should not be funded at this period of tight federal spending. A much better alternative would be to build a coal-to-gasoline plant to reduce this importation of oil that is financially draining our economy.

I cannot just give you my analysis of the coal R & D budget without also presenting the basis for my stong beliefs in the need for realignment of the entire federal budget.

U. S. Energy Perspective

One thing is for certain, it is time that we in this country stop playing politics with our national energy needs and programs. No matter how many jet planes, new ships, or other sophisticated defense projects we build, if we don't have fuel captive to our own natural resources to run them, we will not have a strong national defense. Our nation, and for that matter, any other nation, is just as strong militarily as its energy resources necessary to run that war machinery. Our national threat is not from the Soviets; it is from what Abraham Lincoln once described as our own internal national weaknesses.

The United States exported over $70 billion last year for imported oil. This money left our economy; very little returned and it continues to drain our economy daily like a ruptured artery. The multiple factor of the money exported for imported oil, if it were circulated within our country, is worth about $280 million. You tell me, would not circulating this money back into our economy put Americans back to work and eliminate any national budget deficit?

With regard to coal conversion, only a few utilities have converted from oil back to coal. The government's "hit list" of those utilities earmarked for conversion is nothing more now than a conversational piece of past Administrations. We have nearly 125,000 megawatts of utility boilers burning oil which accounts for over 70 million additional tons of coal production. Of this quantity, nearly 40,000 megawatts of power are generated by those utilities that once produced this same amount of power in the same boilers from coal.

Why have these utilities not converted to coal?

1. No current government push to do so.
2. Utilities can pass the increased fuel cost of oil directly to the customer (via the Fuel Adjustment Act which, by the way, took the incentive away from the utilities to look for the lowest cost fuel).
3. Resistance to change.
4. Environmental regulations have not been relaxed (if anything, they have become more stringent). We only need to relax some of these standards temporarily until we get our industrial growth back on line. Let's reach the balance between energy and the environment like the pendulum that swings back and forth until the balance is reached.

We now have the highest unemployment in the coalfields in over 30 years. Ironically, this is the time when we should be developing our own national coal resources at "full steam" to replace this villain called "Imported Oil." It is almost criminal to think that we are importing 4-5 million barrels of oil daily while millions of tons of coal are stockpiled and thousands of coal miners are out of work. Again, tell me, where are our national priorities?

Conclusion

Consistent with the national objective to reduce federal spending, it behooves us all to spend those resources wisely and in a non-partisan manner to serve the best interest of this country. This Committee should strive to develop a balanced energy program. Our energy needs focus essentially on providing two specific forms; electricity and gasoline. Any federal program should develop technologies to improve the supply of both forms of energy from our own natural resources.

I believe the coal budget in total should be substantially increased by a direct decrease in the current nuclear R & D budget while still holding the total DOE budget to its current level. I also believe we should be constructing at least one major coal-to-gasoline synfuels plant entirely with federal funds much like the Breeder Reactor plant at Oak Ridge, Tennessee, and the Gas Centrifuge Uranium Enrichment plant at Portsmouth, Ohio. We must recognize our national security and economic threat comes from this villain called "Imported Oil" and, therefore, structure our federal R & D funds towards eliminating that single most damaging albatross.

Thank you for this opportunity to present my analysis of the federal energy budget. As national leaders, you must find a way to set a course to obtain national energy independence. The course is long and will, undoubtedly, span several Administrations with different political bias. However, we must stay on course if this nation is to achieve our energy objectives or we will truly repeat Roman history of "fiddling while Rome burns."

RICHARD A. WOLFE, Ph. D.

Vice President - Research & Development
United Coal Company
Bristol, Virginia

Vice President - United Synfuels Corporation
Bristol, Virginia

EDUCATION:

B. S. Chemical Engineering - Virginia Polytechnic Institute - 1961

M. S. & Ph. D. Engineering - University of Cincinnati - 1966, 1972

EXPERIENCE SUMMARY:

1979 - Present: Vice President of United Coal Company in Bristol, Virginia. Responsible for corporate-wide Research and Development. These responsibilities range from improved coal mining techniques to improved coal preparation and conversion of coal to synthetic fuels. Serves as corporate expert and company representative on energy development.

1977 - 1979: Chief, Development Branch, U. S. Department of Energy, Washington, D. C. Responsible for program management of one of DOE's largest development programs. Received two special DOE certificates for superior program management.

1974 - 1977: Program Manager, U. S. Energy Research and Development Administration in Washington, D. C. Responsible for program management of Waste Management and Environmental Control projects. Participated as a representative to the International Energy Agency's Committee on Waste Management. Received ERDA Superior Performance Award for Program Management.

1961 - 1974: Monsanto Research Corporation, Miamisburgh, Ohio. During a thirteen-year period, served in a variety of supervisory and managment positions. Responsible for several major technical and environmental control programs.

HONORS - AFFILIATIONS:

Member of the Virginia Coal and Energy Commission for Commonwealth of Virginia

Vice Chairman of the Virginia Coal Council

1972 - Selected to Who's Who in American Men and Women in Science

Numerous publications in the field of Program Management and Engineering

Mr. **Fuqua**. Thank you very much, Dr. Wolfe.

Dr. Prater.

Dr. **Prater**. Thank you very much, Mr. Chairman, and members of the committee for the chance to talk to you today.

I would like to address one part of the whole picture because my other colleagues on the panel have addressed the other parts much better than I could probably do it. The part that I would like to talk about is liquid transportation fuels from coal. This is the area that I know best because, before I retired to become a consultant, I was manager of process research and development and catalyst research and development at Mobil.

Liquid transportation fuels are a very convenient form to package energy for transportation use since these liquids have a relatively high energy contest per unit volume and are relatively easy to handle. These are conveniences that are going to make it very desirable for us; to use liquid fuels for quite a long time to come if we can have an adequate supply in the future.

There are two technologies that can be used right now to produce transportation fuels from coal. They are the Sasol technologies used in South Africa and the Mobil technology for converting methanol to gasoline. The methanol can be made from coal by existing technology. These two can be implemented today if we have a great need for them. However, there is much work that needs to be done to achieve better efficiencies and economics of coal conversion processes in general because they are not competitive with petroleum today. This kind of work will not be done with private funds in a timely manner and Government support is needed. In spite of the high cost of synthetic fuels from coal and the tight financial situations of the Government and private industry, a synfuels industry will be needed sometime in the future. However, I am concerned about what effect the austerity budget will have on needed synfuel research.

It has been my experience as a manager of research that these times of financial austerity are not necessarily bad times. Such times can be very productive times because they force you away from commercialization of new technologies with its emphasis on engineering of current process concepts to a more basic program that is more inventive but less expensive. Such shifts can produce very startling results. It has been my experience in running research programs at Mobil that these times when you get into a financial pinch are often the time when you really do yourself a great deal of good in inventing new process concepts.

I think that the synfuel program should be considered as part of the defense strategy because that is where we are going to feel it if we get into some real trouble defensewise. Synfuels can have a real impact here and we should look at it in this way. In my opinion, the budget for the basic research program is too small and should be increased by about a factor of three.

I would like to mention a few areas in which basic research could possibly produce very large gains. As you know, coal is deficient in hydrogen and petroleum fuels are high-hydrogen containing fuels. In fact, they might be viewed as a hydrogen fuel with a carbon carrier. The possibility of using hydrogen as a fuel is much discussed now. However, hydrogen is a very difficult fuel to handle in the gaseous state. It needs some way of packaging it; that is, to carry it safely. Liquid fuels, such as those from petroleum, can be viewed as a hydrogen fuel with carbon as the required carrier.

Since coal has very little hydrogen, this hydrogen must come from somewhere and the favorite way of making it now is to react carbon from coal with water. The reactors in which this is done are the gasification and shift reactors. The production of hydrogen is a very expensive part of the process of making synfuels from coal. It is an area in which research can make a very great contribution to reduce the cost of synfuels from coal. It is such studies that certainly should be done in tight financial times because, if you do the basic research correctly, the results will be applicable, for the most part, to any configuration of the process that you may want to use in the future.

There are a lots of big gasification reactors being commercialized at this time. Less money should be put into engineering these reactors and more into using them to obtain basic research information for future improvements. We should try to develop data on them to build predictive mathematical models so that we can determine how future configurations should be.

Another area in which more basic research is needed is in the mechanism of coal liquefaction. Much more efficient processes need to be developed.

There are many areas of this kind and my feeling is that, as a research man that has run large research programs, the proposed funds are too small and should be increased by a factor of three.

Thank you very much.

[The prepared statement of Dr. Prater follows:]

TESTIMONY OF C. DWIGHT PRATER BEFORE SUBCOMMITTEE ON ENERGY DEVELOPMENT AND APPLICATIONS, COMMITTEE ON SCIENCE AND TECHNOLOGY, U.S. HOUSE OF REPRESENTIVES

My name is Dwight Prater. I have a Ph.D. degree in Biophysics from the University of Pennsylvania. Until retirement on January 1, 1982, I was associated with Mobil Research and Development Corp. in various technical and managerial capacities. At present I am working as a consultant on catalytic processes, catalysis, and computer technology. I am a member of the National Academy of Engineering and have served on two committees of the National Research Council on synthetic fuels. Also, I was a member of the Study Group for the American Physical Society on Coal Utilization and Synthetic Fuels Production.

Liquid fuels, such as hydrocarbons derived from petroleum, have proved to be a particularly convenient source of energy for our transportation needs. They have a high energy content per unit volumn and are relatively easy to store and handle. They will be used for a long time if an adequate supply can be assured. Because of strategic considerations and supply problems, production of these fuels from our abundent coal resources will be needed at some time in the future. Although the Sasol and the Mobil MTG technologies are sufficiently developed to be used now to produce transportation fuels from coal, much work is needed to obtain better efficiencies and economics for future synthetic fuel processes. Not all of this will be done with private funds in a timely manner and government support is needed.

In spite of the present surplus of crude, the high cost of synthetic fuels from coal, and the tight financial situation both in government and private industry, a viable synfuels industry will almost certainly be needed in the not to distant future. Such times of financial austerity require carefully tailored and cost effective research programs. These times of financial austerity can be very productive times. The lack of money can force a shift from commercialization of new technology, with its emphasis on engineering of current process concepts, to the more inventive but less costly basic research on the processes of coal conversion to synthetic fuels. The government, universities and private industry should all participate in such a basic synfuels research program.

The problems of production of synthetic fuels from coal can be seen more easily if such fuels are viewed as a part of the hydrogen fuels problem in general. Much discussion and research work has gone into the possibilities of using hydrogen as a transportation fuel. The principle problems are the production of the hydrogen and the packaging of it into a convenient form to be used in transportation vehicles. This packaging is necessary because hydrogen in the gaseous state is dangerous and difficult to handle. Thus, it is necessary to provide an acceptably safe carrier of the hydrogen so that it can be transported on the vehicle and combined as needed with oxygen from the ambient air to provide the energy to move the vehicle. A requirement of this packaging is that it have a high energy content per unit volumn and weight.

One of the most important characteristics of the liquid fuels derived from petroleum is their high hydrogen content. A large proportion of the energy from these fuels comes from the combustion of the hydrogen. Such fuels can be viewed as a hydrogen fuel in which carbon is the carrier of the hydrogen. The carbon carrier is burned and also provides some of the energy.

On the other hand, coal contains relatively little hydrogen. To make a good liquid transportation fuel from coal, a large quantity of hydrogen must be added. The coal provides the carbon carrier of the hydrogen. However, much of the hydrogen that needs to be added must be produced from some other source. The source is water and the most common process is that of reacting some of the carbon in the coal with water at high temperatures. The oxygen in the water combines with the carbon to produce either carbon monoxide or carbon dioxide or both. The production of hydrogen by this process can release considerable carbon dioxide to the atmosphere.

The combustion of petroleum derived fuels in vehicles releases carbon dioxide into the atmosphere. The production of hydrogen by reacting carbon with water will release additional carbon dioxide into the air over and above that produced when the synthetic fuels derived from coal are combusted in the vehicle. Also, more process heat is required to produce synthetic fuels from coal than that required to produce petroleum derived fuels. If this process heat is produced by combustion of carbon containing substances, additional carbon dioxide is released into the atmosphere. It is possible to improve the thermal efficiency of the synthetic fuel processes and thereby decrease the excess carbon dioxide over that produced from use of petroleum derived fuels. Nevertheless, if the hydrogen is obtain from the carbon-water reaction, the use of synthetic fuels derived from coal will always release more carbon dioxide into the atmosphere than the use of petroleum derived fuels.

In recent years considerable concern has been expressed over a slowly increasing carbon dioxide concentration in the atmosphere. This increase is usually attributed to the use of fossil fuels. This increase in carbon dioxide level can cause climatic changes by what is often called the "greenhouse" effect. Sufficient data does not exist to allow a determination of the magnitude of the changes and whether they will have a favorable or unfavorable impact. Opinions of reputable scientists range from catastrophic to beneficial. The government needs to support a reasonable and sustained effort for the long period of time that it will require to collect data to obtain a viable answer to this question. In any case, the length of time required for significant climatic changes to occur should not prevent the establishment of a synthetic fuels industry. In my opinion, the economic, social, and political consequences of the loss of suffucent liquid fuels to sustain ourselves would be more catastrophic than that of the pessimistic scenarios for the effects of slowly increasing carbon dioxide levels. In any case, there are sufficient incentives to reduce the carbon dioxide produced by a synthetic fuels industry in the improved efficiencies and lower costs that accompany such a reduction. The government should support basic research to seek such improved efficiencies and reductions in carbon dioxide formation.

There are two general kinds of processes for producing liquid transportation fuels from coal - the indirect and the direct. In direct processes, essentially pure hydrogen is reacted directly with the carbon of the coal. In indirect processes, the coal is completely broken-down by reacting with water to a mixture of hydrogen and carbon monoxide (synthesis gas). Synthesis gas is a highly reactive substance from which both liquid fuels and chemicals can be produced. It is not at all certain at this time which kind of process will be the most desirable and cost effective. In either case, the production of the hydrogen or the hydrogen-containing synthesis gas is a major cost item. Studies have shown that a proper basic research program on hydrogen and synthesis gas production should lead to a substantial improvement in efficiency and a considerable reduction in cost of synthetic fuels from coal. Research to understand and improve the coal gasification and shift reactions that are used to produce these gases is an excellent candidate for research at this time. The results should be applicable to either the direct or the indirect process. For processes that use the carbon-water reaction as a source of hydrogen, the usefulness of the results should remain even if the commercialization of synfuel processes is delayed for decades. The government should support a considerable research program in this area. Gasifiers under development should be shifted from engineering studies designed for commercialization to research studies designed to understand and model the processes in the gasifiers. Such studies should do much to improve the efficiency and lower the cost of gasifiers.

There are other areas in which productive basic research needs to be done that is broadly applicable to a wide range of possible commercialization of coal synfuel processes. For example, research should continue to obtain a better understanding of the mechanisms of coal liquefaction. The understanding obtained should be used to build predictive mathematical models so that better and more efficient direct liquefaction processes can be developed. Basic research data should be obtained on gasifiers for use in building predictive mathematical models. Search for novel ways to use synthesis gas to produce transportation fuels should continue. The Mobil MTG technology demonstrated what can be done in this area. These are but a few examples of the fruitful areas of research that could serve us well in the future.

In my judgment, the development of synfuel technologies should be viewed as part of our defense strategy not much different from the development of military ships, weapons, and aircraft. Well developed synfuel technologies can certainly contribute to an image of strength. In the time of political crisis they may be much needed.

The $90 million requested for coal research and development for FY 1983 seems inadequate to me in view of the serious situations that can arise in the future from an inadequate supply of transportation fuel. The number should be about three times larger to maintain an effective program.

BIOGRAPHY OF C. DWIGHT PRATER

Dr. C. Dwight Prater was born in Sylacauga, Alabama on January 2, 1917. He recieved a B.S. degree in Chemistry from Auburn University in 1940 and in 1940-41 did graduate work in Physics at the University of Chicago. During World War II, he did basic research studies on radar, magnatrons, and thermionic emissions at the Bartol Foundation, Swarthmore, Pennsylvania. In 1942 he became Research Associate at the Johnson Foundation for Biophysics at the University of Pennsylvania where he carried out research on bacterial viruses, electron microscopy, and electrocardiography. He recieved his Ph.D. in Biophysics from the University of Pennsylvania in 1951.

From 1951 to 1982, he was associated with Mobil Research and Development Corporation in various technical and managment positions. From 1967-1976 he was Manager of Process Research and Development which included catalyst research and development. He retired Janurary 1, 1982 from the position of Senior Scientist & Research Advisor. He is currently a consultant in catalytic processes, catalysis and computer applications to laboratory automation. In the 1982-83 term, he will be associated with the Chemical Engineering Department of the California Institute of Technology..

Dr. Prater is a member of the American Association for Advancement of Science, the American Chemical Society, the Catalysis Society and the American Institute of Chemical Engineers. In 1972 he recieved the Alpha Chi Sigma Award for Chemical Engineering Research from the American Institute of Chemical Engineers and in 1977 he was elected to the National Academy of Engineering.

He has carried out research in Physics, Chemistry and Chemical Engineering. His field of specialties includes chemical kinetics, solid state physics of catalysis, computer technology, heterogeneous catalysis, process reactor design, heat and mass transfer, process modelling, applied mathematics, and synthetic fuel technology.

Dr Prater's early work in chemical engineering was on the kinetics of cracking and reforming reactions in petroleum refining. A paper published in 1958 on the temperature rise during chemical reactions within porous catalyst particles is considered a classic and the dimensionless criterion for estimating this temperature rise is now widely known as the "Prater Number". He was responsible for the development of one of the first kinetic mathematical models of a commercial catalytic process. Some of his most important achievements arose from studies of complex first-order reaction systems. This work represents a major contribution to understanding the selectivity behavior of such systems. Many leading universities have incorporated the techniques developed into the curricula of their undergraduate and graduate kinetics courses.

He was a member of the National Research Council, Energy Engineering Board Ad Hoc Panel on R&D Needs in Refining Coal and Shale Liquids and on the Council's Maritime Transportation Research Board committee on Alternative Fuels for Maritime Use. He was also a member of th American Physical Society's study group on research planning for coal utilization and synthetic fuel production.

Dr. Prater is the author of over 60 scientific and engineering publications and a number of patents. One of his patents was involved in a landmark decision by the Court of Customs and Patent Appeals dealing with the patentability of computer programs.

Mr. FUQUA. Thank you very, Dr. Prater. I gather than one of the differences between your testimony and Dr. Wolfe is that he is for liquefaction and you are for gasification.

Dr. PRATER. Well, you have to remember that the gasification plays in role in both processes, you have got to supply hydrogen.

No, I have worked in both and I don't think it is clear which one will win out. They both need to be supported.

You have to supply the hydrogen for liquefaction from somewhere and the direct processes have to supply it primarily from gasification, shift reactions and the indirect methods.

Dr. WOLFE. I might have misled you about the liquefaction. I really didn't intend to support that greatly. What I was talking about was a liquid coal.

Mr. FUQUA. Oh, OK.

Dr. WOLFE. Now, there is big difference, a big difference, liquid coal, as I use the expression, is doing nothing more than taking the coal, grinding it up like face powder, mixing it with water, putting it into a liquid form for transport and for burning in place of oil.

Florida Power & Light is one of the largest utilities using oil. They are working very closely with us on the Sanford plant to mix coal, not in oil, but coal and water with a chemical stabilizer that makes it like gravy and it is almost a near-term technology, but what we don't know is how you burn it and how you clean the coal down to make it so low in ash in sulfur that it can compete with oil.

And that technology needs to have some additional emphasis. So I see the liquid coal is an intermediate step way ahead, much more immediate than liquefaction.

Dr. PRATER. A little further comment to the so-called liquefaction that is different from his, the one that uses transportation fuels and indirect.

I don't think it can be decided at this time which will be preferable. For instance, the indirect route that produces the syngas, this very reactive substance, that can be used for many things. It is a very nice material to work with and can be used to make your transportation fuels for your chemicals and other things.

It has a lot of attractions. On the other hand, the liquefaction routes may turn out to be more economical but that is not known yet.

Both schools exist, indirect and direct, you don't know which is better.

Mr. FUQUA. Dr. Wolfe, you recommended in your testimony funding for one or two large coal liquefaction plants based on current technology. What technology would you propose and would it be direct or indirect?

Dr. WOLFE. Personally, let me just make the comment that in tight spending like we have, I do believe it is better for this Government to build a synthetic gasoline plant than a nuclear breeder reactor.

Certainly, I think that the technology that is most commercial today needed to build one of these plants, I would propose the indirect method where you take the coal, you gasify it into methanol and then make the methanol into gasoline.

That is the quickest, most commercially available. There are still some problems that right down close to us—20 miles from our office, Tennessee Eastman is doing a coal-to-methanol plant.

They are funding totally with their own funds. But they are really keeping it very basic. There needs to be some supplemental technology development for that.

And I think if this country was going to build one large plant, I certainly would propose that we go from coal to methanol and then from methanol to gasoline.

I think that is far more prudent of our limited dollars then, say, building the breeder reactor, which is $3½ billion or the uranium gas centrifuge program which is $7½ billion that is being built today, as you know, up in Portsmouth, Ohio.

I just think that we are not utilizing our Federal funds very effectively to do those things.

Dr. PRATER. One thing that is not realized about that methanol-to-gasoline process, it is not widely known although it has been talked about some, is that fuel oils can be produced from methanol.

Mr. FUQUA. Dr. White, you mentioned in your testimony the need for several centers of excellence in coal research, each with a stable and long-term funding.

Other than at MIT, where would you suggest it might be appropriate to have those facilities? Or maybe in addition to.

Dr. WHITE. I would prefer not to name locations. There are, however, a number of good locations where——

Mr. FUQUA. I guess really what I was thinking of, should there be GOCO's or university centers?

Dr. WHITE. My preference is on the side of university as contrasted to national laboratories for the simple reason I think that the coupling between the private sector and the universities is better than it is between the private sector and the national laboratories, and it is only for that reason.

Now, there are some national laboratories that I think have reasonable interaction, but I don't think they get high marks in that regard.

Mr. FUQUA. Were you thinking of maybe the one at Sandia at Livermore? The combustion center?

Dr. WHITE. That is not one that I would pick.

Dr. WOLFE. Congressman, could I just make one comment?

Mr. FUQUA. Yes, sir.

Dr. WOLFE. I think that it behooves us all, particularly from industry, to locate some of these coal research centers close to coalfields.

I do think that it is very difficult for us to go to Sandia or go to Livermore and talk. It is a long way from the coalfields for one thing, but if it is at West Virginia University, or if it is at Virginia Tech, which is right in the Appalachian coalfields, or Penn State, it does have impact upon industry being more directly involved than if you have it somewhere located a long ways from the coal.

Dr. WHITE. Might I add, I think an important part of this is that you transfer technology with people. You don't transfer with reports by and large, and to the extent that these centers have a role of training the group of people that will end up in the industry, that will build the processes, I think is critical.

Mr. FUQUA. Dr. Prater, you mentioned the high-priority areas of long-range coal reseach. What did you really have in mind? What are the high-priority areas?

Dr. PRATER. Well, a much better basic understanding of coal gasification, coal liquefaction and how you produce hydrogen and then to build that understanding into predicted models, in which you can use these models to scope out possibly new technology.

This can be done. We have done these predictive models in my experience, and they have been very useful. They can be done and they need to be done badly in the coal area where it is very expensive to build a demonstration plant. We would like to have as much understanding of a conversion process before you sink your money into a large demonstration plant, so that you know it is going to work, you know a lot of the pitfalls. We have used it very effectively, this technique at Mobil, to produce our new processes, and they are very, very effective and they can be done in universities, in industry, and in some of the large facilities.

Some of them you can't do on small facilities like a gasifier, certain experiments have to be done on large ones. But rather than concentrate so much on engineering aspects of these, some of those that exist might well be converted over to at least producing more research data than they are now.

The time of pinching pennies is the time to do this. That is what I found.

Dr. WHITE. I strongly support that position. One of the reasons is liquids from coal are not really required for quite a while and getting that technology straight so that when it is required, we can do it economically is very important

I think Dr. Prater has put his finger on it.

Mr. FUQUA. Thank you.

We appreciate you being here this morning, all three, it was very interesting and very helpful.

The committee will stand in recess while I go vote.

[Recess.]

Mr. **Fuqua**. The subcommittee will resume.

The second panel will lead off with Dr. Robert Davis, from the department of physics at Florida State University, and as I mentioned earlier, was a member of the panel that did the report for the American Physical Society; Dr. Robert Kessler, vice president, energy technology, Avco Everett Research in Everett, Mass.; and Dr. Dayne Aldridge, Energy Research Center, West Virginia University in Morgantown, W. Va.

I understand, Dr. Kessler, that you will be accompanied by Mr. Gannon. We are pleased to have you with us.

Dr. Davis, we are always happy to see you and have your testimony this morning.

STATEMENTS OF DR. ROBERT H. DAVIS, DEPARTMENT OF PHYSICS, FLORIDA STATE UNIVERSITY; DR. ROBERT KESSLER, VICE PRESIDENT, ENERGY TECHNOLOGY, AVCO EVERETT RESEARCH, EVERETT, MASS., ACCOMPANIED BY RICHARD GANNON, DIRECTOR OF COAL RESEARCH, AVCO EVERETT RESEARCH; AND DR. DAYNE ALDRIDGE, ENERGY RESEARCH CENTER, WEST VIRGINIA UNIVERSITY

Dr. **Davis**. Thank you, Mr. Chairman.

Good morning, Mr. Chairman.

Mr. **Fuqua**. Pleased to see you.

Dr. **Davis**. Members of the subcommittee, members of the staff, ladies and gentlemen of the audience, my topic is going to be somewhat narrower than the discussions you heard from the earlier panel members, but I think it is an interesting example of what the Federal Government and industry are doing in connection with one coal utilization problem.

The technology addressed in this research is pulverized coal combustion and in particular, the cleanup of the combustion gases. The title of my remark is "Electron Beam Precipitator Project for the Removal of Fly Ash From Coal Smoke."

I should first comment on the inventory of technical skills. An inventory of scientific skills which are related to coal research, and appropriate to it, should include electron beam technology. There are two applications of electron beam technology underway at the moment, the one is the electron beam precipitator project, on which I will spend most of my time, and the other is an electron beam treatment process for the removal of SO_2 and NO_X, the sulfur dioxide and nitrogen oxides emissions in coal smoke.

The SO_2 and NO_X application of electron beam treatment is represented by two different projects in this country, the one is the AVCO/EBARA project which originates in Japanese research more than 10 years ago. The second one, somewhat more recent, and technically different, is the Research-Cottrell electron beam treatment project.

Both of these projects are now well enough developed for scaleup tests. Such tests are planned and underway with DOE participation. In this case, there has been, and is a productive collabaoration of research institutions and industry and the Federal Government.

I should take a minute or two to assert that electron beam technology is accepted in industry. I find in talking with various groups that there is a momentary cranial arrest as soon as you say electron beam. Listeners somehow think that electron bean systems must still be back in the laboratory, and couldn't possibly be useful, reliable industrial process systems.

Far from the truth. Electron beams are used to treat automobile finishes, the trade name is Electrocure, at the Ford Motor Co. Electron beams are used to treat plastics so that when they are firmly heated they will contract and make nice packaging, electron beam welding is used, for example, in stitching half shells of catalytic converters.

Electron beam technology is here now. What is new is the application of such technology to the processes of cleaning up coal smoke. I have already reported the advanced status of the SO_2 and NO_x projects, the electron beam precipitator project is still in the research phase. This is a high-technology project which certainly does have elements of risk. We like to think of it as excitement, but there are certain elements of risk.

In the project at the moment a precipitator test system has been constructed, the system is unique in the United States, there are similar systems in Japan. This system will be used for precharger design and test work in the next year or two, the results of such work will then form the basis for a decision concerning commercialization of electron beam precipitators as a new technology for removal of coal-fly ash.

As I mentioned already, there is a companion project, companion in the sense that it is using electron beams, a companion project made up of two different efforts to remove SO_2 and NO_X.

These projects are considerably further along, they are obviously research, specifically in a research phase, in fact, they are far enough along for economic assessments to be made, based on some of the reasonable projections on electron beam costs.

These assessments suggest a large savings may be possible, savings in the order of billions of dollars per year.

Now, I would like to comment on new directions of research. First, two points are fairly narrowly directed to the electron beam precipitator, and the second two are more general.

The first point is that there is a new charging mechanism possible, direct electron charging, the details of which I will certainly not go into at this hearing, it is a mechanism which makes use of the specific advantages of the electron treatment beam which are not available in conventional precipitators.

A second point has to do with a special problem in cleaning up coal smoke, which contains high-resistivity flyash. This high resistivity results from the use of low-sulfur coal.

One method of attacking that problem is the reduction of the resistivity by various means. An interesting byproduct of the electron beam research is that electron beams do reduce resistivity of everything.

We would like to find out to what extent this reduction of resistivity can be made a practical application.

The third point has to do with the complete utilization of electron beams. Now, if electron beams are used already as established techniques for the removal of SO_2 and NO_X and indeed, large doses are required for those processes, why not make use of the same electron beams to also go after the particles of coal fly-ash?

This combined treatment idea is an enticing thing to consider and is one of the areas which we see for future research.

Fourth and final, all of the electron beam treatment systems crucially depend upon the cost of the electron beam sources. One very interesting area for advancing the economic advantage of electron beam treatment is to find a way to augment and enhance the dose and consequently reduce the capital costs for the beam sources.

We have shown such an enhancement at Florida State, actually this was anticipated in a somewhat less definitive form by the Japanese 5 or 6 years ago.

It looks good up to the point where we consider power costs. The first enhancement scheme we have chosen, while enticing and exciting, does not have an attractive power consumption schedule. Other means for enhancing electron beams do exist and those should be investigated.

And now finally, a comment or two on the Federal role in future coal research. I think that the previous panel members touched on some of the important ideas outside of coal smoke cleanup and I would generally endorse their comments, with the proviso that research be relevant, on a number of research areas that are cited in the American Physical Society coal study report.

One point which I would like to make, and I do it hesitantly because I don't like to make a point or raise a question to which I don't have an answer that I am happy with. This is the difficulty which we come up against in physics repeatedly. Namely, the tendency to separate basic research and applied research.

If you come up to a point where an application is possible, there is a tendency to "slough it off," which already carries some connotations and separate it from the mainstream of research activity.

I grew up in a laboratory at the University of Wisconsin, where there was no distinction between basic and applied research. It was remarkable how quickly things could move along in both categories when there was an open channel, a two-way street between the problems of basic research and applied research.

I would like to close by mentioning that at the moment, pulverized coal combustion is the dominant coal-utilization technology. It takes a long time to put any other technology in place. Whether or not this technology of pulverized coal combustion will be replaced in the future, and if so, by what, will largely depend upon the success of improvements in pollution control devices.

Such an improvement is the purpose of the electron beam projects that I have reported on today.

Thank you.

[The prepared statement of Dr. Davis follows:]

9/13/82

Statement Before
the Subcommittee on Energy Development and Applications
U. S. House Committee on Science and Technology
Washington, DC September 16, 1982

ELECTRON BEAM PRECIPITATOR PROJECT
FOR THE REMOVAL OF FLY ASH FROM COAL SMOKE

Dr. R. H. Davis
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Florida State University
Tallahassee, Florida 32306

These remarks are organized to address the perceived purposes of the subcommittee: to inventory scientific skills and technologies appropriate to coal research, to assess the progress of ongoing programs, to identify promising new directions and to determine the federal role in future coal research. I am pleased to have the opportunity to present them to you.

INVENTORY OF ELECTRON BEAM TECHNOLOGIES RELEVANT TO COAL RESEARCH

For completeness and because the projects are related in important ways, the inventory should include the electron beam precipitator project and the established processes used for SO_2 and NO_x removal. Two different properties of energetic electrons in gases are utilized in each. The electron beam precipitator utilizes the copius ionization produced by energetic electrons. The SO_2 and NO_x control processes depends on the production of oxidant radicals which through a series of chemical reaction convert the SO_2 and NO_x into products which are more easily removed.

Other properties of external electron beams are already used in routine industrial processes. Plastics and paint coatings are routinely treated in reliable production lines.

Non-vacuum electron beam welding has a number of applications such as stitching the half-shells of catalytic converters. Reliable electron beam sources are commercially available. What is new is the use of such beams in pollution control devices.

PROGRESS OF ONGOING PROGRAMS

The electron beam precipitator project is in the research phase. An electron beam precipitator test system has been contructed for this research at the Florida State University. This system is unique in the United States in that it combines research capabilities in both electron beam treatment of aerosols and electrostatic precipitation.

A program of precharger design and test is underway. Such devices address the major problem in pulverized coal combustion today, that of removing the high resistivity ash produced by the combustion of low sulphur coal. Precipitation is divided into two stages: particle charging (or precharging) and collection. Improved particle charging is the key to improved performance.

The two projects on the removal of SO_2 and NO_x by electron beam treatment are more advanced. The AVCO/EBARA process is based on research in Japan more than a decade ago. In addition to the removal of SO_2 and NO_x, the process yields a fertilizer as a byproduct.

Research Cottrell has developed a process for SO_2 and NO_x control which incorporates a dry scrubber and electron beam treatment. Advantageous and cooperative use is made of the properties of dry scrubbers and electron beam treatment.

Both the SO_2 and NO_x removal processes are ready for scale-up tests and projects to accomplish these are going forward with appropriate DOE participation. The problem of particulate matter control is rather different in the SO_2 and NO_x processes because of the required conditions of moisture and temperature. It would appear to be simplier since the high resitivity problem is avoided and it is enticing to consider a system which uses electron beams for the removal of all three SO_2, NO_x and particulate matter (SOX, NOX and ROX).

All of the electron beam treatment systems crucially depend on the cost of the electron beam sources. The SO_2 and NO_x systems are well enough advanced for economic assessments. Based on reasonable projections of electron beam source costs, these assessments suggest that large savings are possible, as much as several billions of dollars per year.

PROMISING NEW DIRECTIONS OF RESEARCH

The first two points are specifically related to the electron beam precipitator research while the second two are more general.

There is evidence that direct electron charging of particles, that is the attachment of an electron to the particle without an intermediate ionic state, can significally increase the particle charge and the completeness of subsequent precipitation. This charging mechanism is not well understood but is important since an increase in the number of free electrons is expected in electron beam precharger devices.

Electron irradiation reduces the resitivity of materials. Preliminary experiments show that reductions in resistivity of factor of 50 can be obtained in dust layers. An unexplained but curious result is the persistance of this reduction over periods of tens of hours. Experiments to assess resistance modifications while the particles are entrained in gas have not been done.

An area of common interest with the SO_2 and NO_x control projects is that of particulate matter removal. The conditions for fly ash removal are certainly different in the SO_2 and NO_x removal processes principally because the increase in humidity and reduction in temperature eliminates the high resistivity problem. There remains the interesting possibility of using the large doses required for SO_2 and NO_x removal in an combined treatment system for the control of all three SOX, NOX and ROX. A workshop to discuss the realities of this possibility was organized last February.

The capital cost of the electron beam sources is the important factor in economic assessment of electron beam treatment systems. Methods to enhance dose with the corresponding reduction in beam source capital costs are being investigated at several laboratories following earlier Japaness work which showed that increased SO_2 and NO_x removal resulted in the presence of an electric field. Work at Florida State University has definitively proven the existence of dose enhancements by imposition of electric fields. That good news is seriously eroded by the conclusion that power consumption for a given dose is discouraging high for dose enhancement by DC electric fields. Other means of dose enhancements should be investigated.

FEDERAL ROLE IN FUTURE COAL RESEARCH

Federal support of basic research in coal physics and chemistry is essential. Such basic research lays the foundation for new technology, provides the intellectual ferment necessary to invent the technology and, through graduate education, trains the next generation of scientists and engineers. A number of research areas are cited in the report of the American Physical Society Coal Study Group.

A more difficult problem is the relationship between the basic research and applied research. The process by which an idea moves from a basic research result to an application and then on to a technology is clear enough. What isn't generally recognized is that the reverse is true. Excellent talent doing applied research and development work will also create new areas of basic research. A more flexible accommodation of this two way flow would expedite progress in both basic and applied research.

Pulverized coal combustion is the dominant coal utilization technology today. Whether this technology will be replaced in the future and, if so by what, will be largely determined by successful improvements in pollution control devices. Such an improvement is the purpose of an electron beam precipitator project.

9/8/82

BIOGRAPHICAL SKETCH

Dr. Robert H. Davis
Department of Physics
Florida State University
Tallahassee, Florida, 32306

Dr. Robert H. Davis was born in Long Island, New York in 1926 and grew up in Milwaukee, Wisconsin. After service in the Navy in World War II, he studied physics and mathematics at the University of Nebraska and graduated in 1949. Dr. Davis earned the Ph.D. degree in experimental nuclear physics at the University of Wisconsin in 1955, after which he was a Research Associate at the Rice University in Houston, Texas. He came to the Florida State University as an Assistant Professor of Physics in 1957 where he became immediately involved in the planning and installation of the Model EN Tandem Van de Graaff Accelerator, the second in the U. S. For ten years beginning in 1963, Dr. Davis served as the Principal Scientist of the Florida State University Tandem Van de Graaff Accelerator Laboratory during which time the research program achieved an international reputation and the laboratory was awarded an NSF Science Development grant for the replacement of the Model EN machine by a more powerful Super FN machine in 1970. In 1979 he was elected chaiman of the Department of Physics and has been re-elected for a second term.

Most of Dr. Davis' basic research publications are in the field of nuclear physics with additional publications in ultra-high vacuum technique, active solid state electronic devices, and heavy ion sources. His interest in energy research began before the Arab oil embargo and has included problems in solar, fusion, MHD, and coal combustion systems.

Since 1978 he has concentrated on the development of electron beam precipitators for the removal of fly ash from coal smoke. The test system recently constructed for this research is unique in the U.S. in that it provides research capabilities in both electron beam treatment and electrostatic precipitator technology.

Dr. Davis lives at 726 Ivanhoe Drive, Tallahassee, Florida with his wife Patricia. They have two children, Pamela and John.

MEMBER: American Physical Society
American Association for Aerosol Research
Florida Solar Energy Center Technical Advisory Committee
IEEE/IAS Energy Committee
Governor's Energy Task Force

Mr. **FUQUA**. Thank you very much, Dr. Davis.

Dr. Kessler.

Dr. **KESSLER**. Thank you.

My name is Robert Kessler, I am the vice president for energy technology for the Avco Everett Research Lab and I have with me today, Mr. Richard Gannon, director of coal research.

I have submitted written testimony with some backup technical material which I would like to include.

What I would like to testify——

Mr. **FUQUA**. We will make all of your statement part of the record and if you wish to summarize.

Dr. **KESSLER**. Thank you. I am not going to read the submitted testimony.

I would like to testify in favor of a strong federally supported R&D program aimed at developing improved technologies for coal processing.

What I would like to talk about is the need for such a program, some results of previously federally supported work, examples from our own experience of technology with a good potential for being useful in coal conversion, and finally, what we would like to see in a Federal program, and especially how we would like such a program implemented.

Coal, as we know, is the most abundant fossil energy resource in the United States, with about 200 billion estimated tons of economically recoverable reserves and some trillions of total resources.

The national interest would benefit greatly by increased use of these coal reserves, especially to substitute for oil and gas. The benefits would be increased security of our energy supply, improvement in balance of payments, and lower cost energy for a variety of uses.

These things are well known.

In order to realize these benefits, I believe we need new technology for converting coal to liquids and gases and new technologies for using coal in pulverized form in order to compete with oil and gas.

Past programs aimed at these results have been, I believe, unduly influenced by the energy crisis climate of the past 10 years or so.

The programs were aimed at producing short-term results and therefore made use of existing processes and technologies or small improvements to them.

The scale at which these needed to be demonstrated was large and required pilot plants or demonstration plants of large enough scale so that large amounts of dollars would have been needed.

In many cases, the improvements of these technologies over existing 30-, 40-year-old gasification and liquefaction technologies based on German work going back to the beginning of the century was marginal.

The result of all this was that really new technologies based on results of the last 10 or 15 years received little attention because the results would have been too far away to meet the immediate needs.

The result was a sort of a Catch-22 situation in which promising new technologies would receive no support until results were shown and, of course, no results could be obtained without support.

So now, I believe we have a situation in which we need new technologies to permit substitution of coal for oil and gas. To develop these new technologies, we need a strong R&D program which necessarily takes a long time, as is the nature of R&D, and must be started well in advance of the time when the technologies are needed if they are to be available.

Now we come to the question of how such a program is to be supported. I do not believe that private industry will support such a program because the results are too far away to make the investment attractive, the risks are high, the payback is not predictable, and is too long delayed.

Second, the incentives for such a program are based on national interest concerns which do not translate to specific market incentives.

For those reasons, private industry has not, and I do not believe they will, support such a program. Yet the national benefits are so great that I believe such a program is necessary and, therefore, the Federal Government should be responsible.

I would like to cite now some examples of technologies in which the Federal Government has been involved, and without whose involvement, these technologies would not exist.

The ones I will cite are the examples that we at Avco have firsthand experience with: coal gasification, coal combustion, MHD, and the one Professor Davis referred to, electron beam treatment for cleanup of flue gases.

I will not go into the details of these processes. I want to make only the points that each of these has potential for allowing coal to be substituted for oil and gas in a variety of different applications, none of them would have existed without Federal support and that there are many new such technologies that others are working on that also will not exist without Federal support.

Private industry, as I said, will not support such programs in their early stages because of the uncertainties, the risk, and the large investments required.

What we would like to see, then, is a clearly defined, long-term energy policy that would form the framework for a coal-based R&D program. The objectives of the program would be basic coal research and development of coal science, its chemistry, its reactions, its structure.

It would include also the exploratory development of new processes which would allow the conversion of coal to gases and liquids that could replace oil and natural gas.

I would particularly like to emphasize the need for stability in such a program. The goals should be well thought out and adhered to and the program should be consistently implemented and funded.

I think that the past large swings in funding and the changes in program directions and goals have been very detrimental to the achievement of any goals at all and have wasted an enormous amount of money.

Research and development is necessarily a long-term process and requires stability in direction and of funding in order to achieve results.

Thank you for this opportunity to testify.

[The prepared statement of Dr. Kessler follows:]

Statement of

Dr. Robert Kessler
Vice President, Energy Technology Office
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for

The Subcommittee on Energy Development and Applications

of

The Committee on Science and Technology
U.S. House of Representatives

16 September 1982

SUMMARY

Full realization of the economic, environmental and national security benefits offered by greater use of the nation's large coal reserves requires the development of advanced processing techniques that will make coal an attractive alternative to oil and gas. New technologies developed during the past twenty years have the potential for making coal a viable substitute for oil and gas. The testimony reviews several of these and gives examples of resulting technological fallout.

The programs which have given birth to the new technologies have been supported largely by the Federal Government. Without Federal Government support, these technologies would not exist and without continuing government support other promising technologies will not be developed. Private industry will not support such programs because the requirements are not driven by predictable and specific market needs, and because the returns on the necessary large investments will be delayed too long to be competitive with other investment options. The national interest justifies federal support for developing advanced coal processing technologies to a point from which industry can assume a role in development and commercialization.

A federal program should emphasize advancement of coal science, and exploratory development of advanced technologies with long-term objectives rather than the short-term objectives which have characterized federal coal R&D over the past ten years. The importance of energy to our national security dictates a clearly defined long-term energy policy consistently administered and supported by actively funded energy R&D programs.

Statement of

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Coal is the most abundant fossil energy resource in the U.S. It is estimated that over 200 billion tons of coal are economically recoverable, and that there are more than 3.9 trillion tons of total coal reserves. Increased use of this vast resource would yield great national benefits, such as increased security of our energy supply, improvement in our balance of payments position and possible lower cost energy for a variety of uses.

Full realization of these potential benefits will require substantial technical advances in several areas over presently available technology. A broad and sustained program is required (i) to develop a better understanding of coal structure and coal chemistry, (ii) to develop technologies capable of converting the chemical energy in the coal to more useful forms of energy in an economically and environmentally acceptable manner, and (iii) to develop improved process control methods and diagnostics. The necessary research and development work is formidable, and must be performed well in advance if it is to be available for commercial development when needed.

How is such a program to be supported? It is argued that private industry will undertake the necessary development in response to market forces. Although a strong case can be made that private industry should be heavily involved in the work, on the grounds that it alone can bring technologies to the market, it is highly unlikely that the private sector will finance such a program.

The scope and duration of the extensive development for advanced coal utilization systems means that the return on the necessary large investments will be delayed too long to be competitive with other avenues for private investment. However, there are requirements that are driven by national interest needs for which only the government has the responsibility to respond. For example, while there is a widespread consensus that coal-derived gas and liquids will eventually be required, no one can say with any certainty when these technologies will be needed on a commercial scale. Nonetheless, for our own national interest, we should maintain an ongoing R&D program to insure that new coal conversion technologies will continue to advance so as to be available when needed.

In assessing the effectiveness of federal programs in coal R&D it appears to us that the programs have been unduly constrained by the energy crisis climate of the past ten years. Facing what was perceived to be imminent oil and gas shortages the Federal Government reacted by funding programs that promised measurable improvements in coal conversion processes within a period of a few years. With such short term objectives the program necessarily emphasized improvements in existing processes that promised small but achievable advances in the technology that had existed since the 1930's, or accelerated development of new technology that had not been adequately studied. Unfortunately the scale at which the projected advances had to be demonstrated required large pilot and demonstration facilities and commensurately large funding levels. In addition, subsequent estimates of the costs of commercial plants based on the so-called second generation designs showed that the projected improvements over first generation processes were at best marginal. Consequently most of the second generation process development work has been discontinued, leaving the impression that the use of coal under current sociological, ecological and economic constraints is not very attractive.

Relative to the emphasis and large expenditures of the pilot and demonstration plant programs, research and development programs that explored the application of technology in ways that departed from existing coal practices were given little attention. Promising technologies that were developed in the aerospace and chemical industries during the 1950's and 1960's were not explored, chiefly because they could not be projected as affecting coal processing practices within the time limits imposed by the pending oil and gas shortages. Many companies with experience in developing new technologies found themselves in a "Catch 22" situation: DOE would not fund them to develop necessary engineering design data until they had demonstrated the potential benefits of the specific technology advance, and they could not demonstrate its potential until they had developed the necessary engineering design data.

In order to make the use of coal competitive with oil and gas, new technologies are necessary that represent departures from traditional coal processing practices. With the exception of direct coal-burning, existing coal conversion technologies have failed to make the use of coal attractive enough to encourage significant coal usage by industry. Many new technologies exist which originated with exploratory research programs supported by the Federal Government and which now are recognized for their potential for making coal a viable substitute for oil and gas. To illustrate, I cite four such examples with which Avco Everett Research Laboratory, Inc. has had first hand experience.

Coal Research & Development at Avco

Over the period 1965 through 1972, some limited observations of coal behavior suggested that up to 80% of the total mass could be converted to gas (volatiles) by rapid heating to high temperature. Until this period, it was traditionally accepted that volatiles were fixed at much lower levels which could be defined in an absolute sense. It is on this basis that most coal conversion processes have been developed to date.

The major value of the high volatile yield behavior is that it allows a large fraction of the coal to be converted to gas, without dependence on reaction of other gases with solid carbon. This reaction is slow, requires high temperature, and can dominate equipment size and operating costs. By minimizing it, through use of rapid coal heating and the associated high volatile yield, major technology improvements are possible. Researchers at Avco Everett have explored the high volatile yield behavior, and have developed a basis for understanding and quantitatively predicting the direct thermal decomposition of coal. We have begun to exploit this behavior in the development of novel technologies for gasification and combustion.

Coal Gasification

The key to the gasification system devised by Avco is based on the discovery that, at heating rates of 10,000°C per second and higher, coal releases up to 80% of its carbon as gas in less than 100 milliseconds.* Once the coal carbon is available as gas, rather than as a recalcitrant solid, the reactions become much more predictable and controllable.

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* This observation was reported by Avco in its Final Report to OCR on Contract No. 14-01-0001-493 in 1972. Workers at BCURA in England reported it about the same time. Enhanced volatile yields obtained at high heating rates is now generally accepted by the coal scientists but process designers need definition of its limits before incorporating into their plant designs. A review of the observation of enhanced volatile yields by various workers is given in a paper by Ubhayakar, Stickler and Gannon published in Fuel, Vol. 56, July 1977.

The system has the potential to reduce drastically plant size and product cost. For example, when compared to the Great Plains coal gasification plant now under construction in North Dakota using 1930's German Lurgi technology, a plant using the Avco technology would require only 2 gasifiers, compared to 12 or 15 Lurgi gasifiers. The oxygen demand would be reduced to approach the theoretical minimum without producing the troublesome liquid by-products which would be found using Lurgi gasifiers. With a projected product price of about $10 per million/Btu, the use of Avco technology in a plant of the same size as the Great Plains plant would represent a savings of about $90 million per year (Fig. 1).

Another advantage allowed by the Avco approach is that, because of its small size, slag protection of the reactor walls is practical. This technology, which was developed as an outgrowth of MHD research, permits the elimination of high temperature slag-resistant refractories which add costs and maintenance problems to conventional and second generation gasifiers.*

The Avco Gasification System is designed to produce a synthesis gas which can be burned either as an intermediate Btu fuel or further processed to produce transportation fuels, pipeline gas, or electricity. Preliminary plant designs for each of

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* Details of the development of slag protection technology and its projected application to coal processing methods is given in a paper by Stickler and Gannon published in the Proceedings of the International Gas Research Conference in Los Angeles in October 1981.

	LURGI	AVCO
BILLION BTU/DAY		
PROCESS COAL	190	190
TOTAL COAL INPUT	230	190
PRODUCT SNG.	125	130
THERMAL EFFICIENCY	56.3%	68.3%
CAPITAL COST*	\$458M	\$345M
RELATIVE PRODUCT COST	1.00	0.79

*1978 COST ESTIMATE BY R.M. PARSONS CO.

K5955

Fig. 1 Cost Comparison of Avco and Lurgi Gasification Systems

these options indicates the Avco System has potential process and economic advantages in each case.*

Avco is currently conducting a research program to define the limits of steam pyrolysis, one of the critical steps of the process, under an ongoing DOE contract.

Coal Combustion

A major problem in converting gas or oil fired boilers to coal is the excessive fouling of the boiler tubes by coal ash. A solution being considered by DOE is to remove the major portion of the ash as slag in the combustor prior to its entrance to the boiler. Avco has explored the applicability of the new technologies, namely rapid devolatilization and slag protected walls, that it has developed on the Coal Gasification and MHD programs, to the design of a slagging coal combustor that could be used to retrofit existing gas or oil-fired boilers (Fig. 2). With such a design, up to 90% of the ash is removed as slag from the combustor. This technology may also open opportunities for greater use of anthracite, which is now difficult to burn using existing industrial technology. Avco has received Federal support for combustor development as part of the MHD program and now has proposed to investigate it as a solution to the boiler retrofit problem.

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* These designs are described in the following reports:

1. "A Screening Evaluation of Rapid Devolatilization Processes," GRI Contract No. 5010-322-0048, August 1978.
2. "Indirect Liquefaction via the Avco Coal Gasification System," IECEC Meeting, Seattle, Wash., August 1980.
3. "The Avco Gasifier in a Combined Cycle Power Plant," IGT Symposium, April 1981.

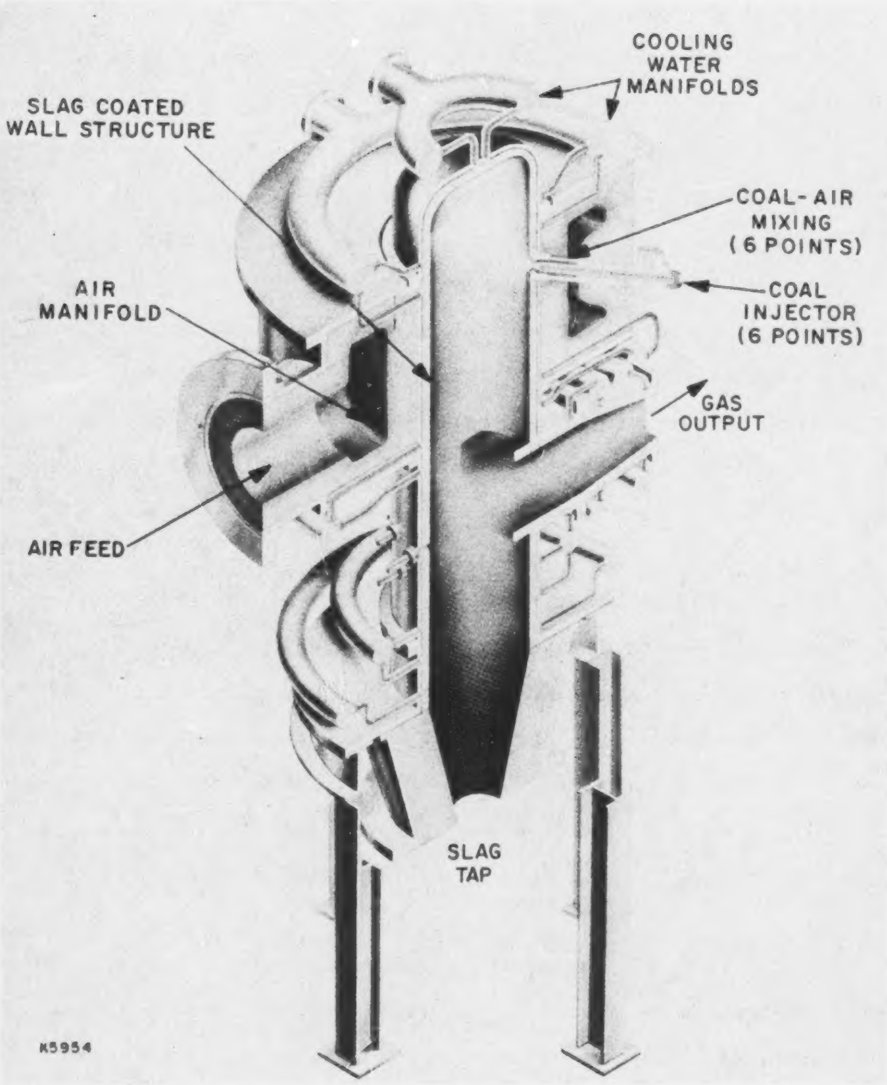
COOLING WATER MANIFOLDS
SLAG COATED WALL STRUCTURE
COAL-AIR MIXING (6 POINTS)
COAL INJECTOR (6 POINTS)
AIR MANIFOLD
GAS OUTPUT
AIR FEED
SLAG TAP
K5954

Fig. 2 Slag Rejecting Coal Combustor

Generation of Electricity

While I realize that the committee is familiar with magnetohydrodynamic (MHD) power generation, let me review briefly for the record the technology and its advantages before describing recent advances. Conventional power plants produce electricity at an efficiency of less than 35% and if they burn coal they also present pollution problems. MHD is an advanced electricity generation process that promises efficiencies of greater than 45% and that can use high sulfur coal with minimal environmental intrusion. The MHD process utilizes high temperature electrically conducting gas, produced by the combustion of coal, which is passed through a magnetic field to generate electricity. The potassium salt which is added to increase the conductivity of the gas also acts to remove the sulfur before it is emitted. It is estimated that compared to conventional steam plants, savings in the cost of electricity up to 20% can be expected with the use of MHD.

MHD development has shown substantial progress over the past several years. The recent completion of a 1000 hour duration test of the anode wall of the generator indicates that lifetimes of between 5000 and 8000 hours can now be projected for this critical component.

During the past few months a successful test was completed in which an MHD coal combustor developed by the TRW Corporation was operated with an Avco channel (generator) at the Avco test facility in Everett, MA (Fig. 3). This was the first operation of a slag-rejecting coal combustor with an MHD channel.

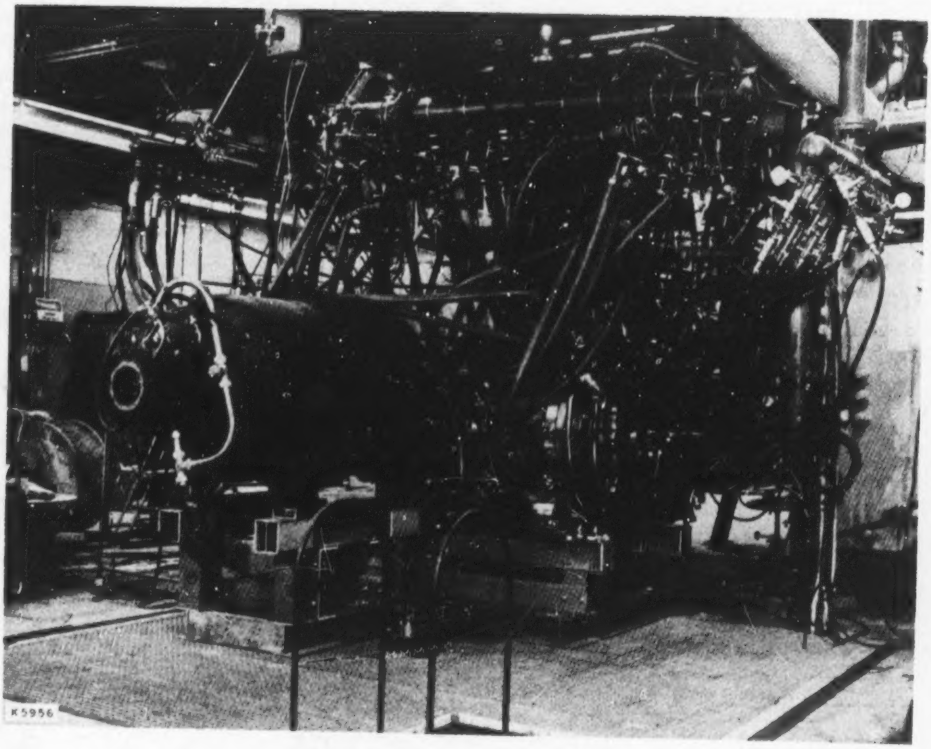

Fig. 3 Avco Mk VI Test Cell with TRW Combustor

The Government's investment in MHD has resulted in new concepts and advances in several technologies. The following are a few examples:

a) slag-rejecting coal combustors, which are now of great interest as possible means of retrofitting existing oil-fired boilers to use coal with minimal performance degradation;

b) slag handling technology, now being applied to the development of low heat loss wall structures for coal gasifiers and coal combustors;

c) high temperature corrosion-resistant materials;

d) superconducting magnet technology, which will be useful to the development of fusion power and superconducting rotating machines; and

e) greatly increased knowledge of high temperature gas flows and plasma-dynamic phenomena.

Stack Gas Clean-Up

Traditional methods for removing sulfur from coal combustion products require the use of large wet scrubbing towers and the associated problems of handling large quantities of liquids for the scrubbing process. The current thrust of control efforts for nitrogen oxides involves precise control of combustion behavior, or a form of afterburning in the boiler.

The concept that Avco is exploring is a major departure from these approaches. It involves the use of electron beams in the presence of ammonia to treat the stack gas in a selective manner.

This process converts both the sulfur and nitrogen oxides to a dry powder that can be marketed as agricultural fertilizer. This approach also improves overall particulate capture. The process is completely dry with no slurry recycling or sludge disposal requirements. Studies by a power plant architectural and engineering firm indicate substantial reductions in both capital and operating costs. Also, the technology is compatible with current power plant practice and personnel capabilities. With the support of DOE, Avco is currently designing a pilot-scale treatment system to be tested at a coal burning utility site.

The examples cited are illustrations of advanced technologies applied to coal processing problems. Each is a departure from current industrial practice but each promises significant economic advantages. Without Federal Government support these technologies would not exist. Without continuing Government support many other such advanced technologies will not be developed. The required development time means an extended payback period that has discouraged private industry from support of emerging processes. It is these technologies for which Federal support is required to develop them to a point from which industry can assume responsibility for continued development and commercialization. In some cases, this may require Government support through pilot-scale testing.

A clearly defined, long term energy policy is required which is aimed at providing the necessary basic design data to enable industry to make knowledgeable decisions regarding the beneficial use of coal. Changes in Government policy and goals, and large swings in DOE funding over the past few years, have resulted in policy indecision which has led to confusion as to national energy policy and has too often discouraged industry from aggressively participating in energy technology development.

The U.S. can insure its energy security by vigorous development of its domestic coal reserves and the technologies for using them. These should include improved mining techniques, MHD power generation, coal gasification, coal liquefaction, coal beneficiation, improved combustion technologies and environmental protection methods. The importance of energy to our national security dictates that an energy program in general, and a coal R&D program in particular, be clearly defined as a long term policy, which should be consistently administered and supported by an active federally funded energy R&D program.

BIOGRAPHY

DR. ROBERT KESSLER
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Dr. Kessler is Vice President of the Energy Technology Office, responsible for all energy-related activities at AERL. These include programs in coal gasification, coal combustion, MHD power generation and flue gas clean-up. Dr. Kessler also serves as Program Manager of the MHD Generator Component Development program.

Dr. Kessler received his B.S. and M.S. degrees from Massachusetts Institute of Technology and his Ph.D. degree from Stanford University in Mechanical Engineering. He did post-doctoral work at the U.S. Naval Postgraduate School, where he was also a Visiting Assistant Professor.

Prior to joining Avco, Dr. Kessler was a Research Associate at Stanford University where he was responsible for directing laboratory operations of the High Temperature Gasdynamics Laboratory. He conducted research on combustion-driven MHD generators and participated in the supervision of Ph.D. and M.S. students working in the fields of MHD, gas-dynamic lasers and combustion-generated air pollution. His prior industrial experience includes two years at the RAD Division of Avco.

Dr. Kessler is an Associate Fellow of the American Institute of Aeronautics and Astronautics, and a member of the American Society of Mechanical Engineers, the Steering Committee on Engineering Aspects of Magnetohydrodynamics, and engineering and scientific honor societies. He has authored many papers related to MHD power generation.

BIOGRAPHY

MR. RICHARD E. GANNON
Director of Coal Technology
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Mr. Gannon has Masters Degrees in Chemistry from the University of Connecticut and in Chemical Engineering from Lowell Technological Institute.

He is Principal Research Engineer in the Energy Technology Office at AERL, responsible for the evaluation of coal conversion processes and serves as coordinator for the Laboratory's Coal Working Group. He is manager of the Avco Coal Gasifier Development Program and of a basic research project to study the effects of coal structure on its reactivity. Previously, Mr. Gannon was responsible for integrating coal gasification with MHD power generation and was in charge of the development of a commercially feasible process for the conversion of coal to acetylene. In addition to his managerial duties, which included subcontractor coordination and pilot plant design, he was also responsible for the evaluation of the effect of process variables on product yield and on the investigation of the kinetics of the reactions involved.

He joined Avco Systems Division in 1956 where he was involved in programs for the development and evaluation of materials for space flight and industrial applications. He served as program manager for the investigation of failure mechanism exposed in the underground nuclear tests. He has also studied the chemical action of fuel components on rocket nozzle materials and has worked on various surface protection problems.

He has authored and coauthored papers published in the following journals: The Physics and Chemistry of Solids, the Electrochemical Society, The American Institute of Aeronautics and Astronautics, Industrial and Engineering Chemistry, American Ceramic Society, Institute of Environmental Sciences, Solar Energy and in the Proceedings of MHD Symposia. He has also presented papers at meetings of the American Chemical Society, The American Physical Society, the American Institute of Chemical Engineers, the Conference on Crystal Growth and the Solar Energy Society, as well as at Symposia on Thermal Radiation and Magnetohydrodynamics. He has been chairman of AIChE Conference Sessions on MHD Power Generation and on Advanced Power Generation Systems. He has been issued two patents on Coal Gasification.

He is a member of Phi Lambda Upsilon, Sigma Pi Sigma, and Sigma Xi and the American Institute of Chemical Engineers.

Mr. FUQUA. Thank you very much, Dr. Kessler.

Dr. Aldridge.

Dr. ALDRIDGE. My name is Dayne Aldridge, I am director of the West Virginia University Energy Research Center and professor of electric engineering.

For the past 13 years, I have conducted research on coal mine safety and productivity issues. More recently, I have been coordinating a $15 million energy research program, which involves a wide range of coal-related subjects.

I also serve as a member of the West Virginia Coal Development Authority.

I want to thank you for this opportunity to appear here today. The hearings that you have previously held on coal research have provided information on a number of different topics which are very important. I want to stress the importance of recognizing that the subject of coal research does cover a wide range of subjects: exploration, extraction, cleaning, transportation, liquefaction, gasification.

Other topics such as occupational safety and health, productivity, environmental protection, cuts across all of these lines. Today I will limit my comments to three major points which I believe are critical to the federally sponsored program of coal research.

Moreover, I believe each of these points has never been adequately emphasized and, in some cases, are not presently recognized as factors in our national energy research program.

Point No. 1. Exploratory or basic research is important to all aspects of coal-related technology. I want to emphasize the word "all" because you have heard today and in previous testimony about the importance of our understanding the basic chemical and physical properties of coal and the reactions involved in the conversion and cleaning process.

I want to not only affirm this fact but also to emphasize the critical importance of a strong exploratory research effort as a foundation to each applied area of coal research.

In my opinion, this has been one of the shortcomings of the DOE fossil energy program and historically has been a problem with coal research in this country.

True innovation in the applied areas must evolve from exploratory and basic research activity. The more fundamental discoveries are the "seed corn" for advances in the real world of production.

While it is true that currently known coal conversion technologies are not economically competitive with imported liquids, it would take only one fundamental discovery to change that balance.

Similarly, the knowledge base that we apply to other areas such as exploration, extraction, cleaning, et cetera, could be transformed through fundamental scientific engineering discoveries.

It deeply disturbs me that we seem to have lost faith in mankind's ability to innovate, discover. Too often, Government-sponsored applied research programs require that the breakthrough be almost certain before the research funds are awarded.

This is not research, it is a marketing game. It might be characterized as saying "Pay me for the solution now that I have found it."

This attempt at reducing the risk of Government-funded research has led us to bankruptcy in many applied areas. Without the seed corn, the farm ceases to produce.

Ladies and gentlemen, I submit that we have arrived at this situation in some coal research areas, such as the one I will discuss next.

Point No. 2. Underground coal extraction research should be a high-priority topic in our national energy program.

It is not.

Of our 475,000 million tons of total mineable reserves, 67 percent is expected to be mined through underground methods. Of the eastern reserves that are the most likely to provide for export to the European market, 80 percent is expected to come from underground mines.

As the easier-to-acquire coals are depleted, much of which will come for surface mines, we will be forced to deal with deeper and thinner seams that will be more expensive, possibly less safe to mine than possible with present technology.

The United States has been described as the Saudi Arabia of coal. This has inferred to many that we can automatically expect to play a commanding role in the future world energy market, especially as we compete with other producers of coal.

I submit that we do not have a monopoly on coal. There are many competitive forces at work in the world coal market.

Today we do not deliver the least-expensive coals to Europe. Their buyers say that our coal exports have remained high, despite uncompetitive prices, simply to assure a reliability of supplies.

The virtual monopoly of Australia, South Africa, and the United States is now in the process of being broken by Poland's reentry into the marketplace and will be further eroded in the future by the People's Republic of China and other countries such as Botswana.

We must plan now to assure our long-term competitiveness in the world coal market. The technology we apply to the underground mining of coal at the turn of the century will play a key role in our position in the international energy arena.

Today there is no Federal commitment meeting this long-term need. Some will argue that there are no innovations on the horizon to dramatically affect underground mining productivity and thus a major coal mining research and development program is unlikely to produce worthwhile results.

I submit that this is true, because we have had essentially no investment in exploratory research in this arena. There is no seed corn, so the farm cannot produce.

Others will argue that such research is the responsibility of the mining industry, especially the manufacturers of mining equipment. While they do have a research role to play, I call two factors to your attention.

First, our mining industry is highly fragmented. The long-term competitive edge for a mining company comes from good systems engineering, that is, the efficient use of an array of devices and apparatus which are generally available to all miners of coal.

Component innovation is left largely to the manufacturer and thus is available to all users.

The second factor is the international nature of the mining equipment market. U.S. manufacturers must compete with foreign entities who enjoy Government-sponsored research and development in arrangements where the laboratories and mines are Government-owned or subsidized.

This has led to countries such as the United Kingdom, Germany, and France developing and exporting new mining technology to the United States. And I might add, using high technologies, such as electronics developed in this country.

Thus, I strongly advocate a high priority for exploratory research related to the underground extraction of coal, with the broad objective of meeting our long-term needs.

The third point I wish to raise relates to the topics I have just discussed. However, it has a much broader implication than just coal mining, it relates to our whole coal research development strategy.

Point No. 3. Coal should be a key factor in our long-term planning for national security and international stability.

Given the events of the past 10 years and the demonstrated importance of energy resources in international affairs, I cannot understand the current lack of attention for coal in the formulation of international policy and military planning.

The current strategy of depending primarily on the strategic petroleum reserve to offset the disruption of oil imports has implications which greatly concern me.

First, this strategy is predicated on the assumption that disruptions will be short-term in nature. And I ask, what is the second line of defense if conflicts should be sufficiently long to severely deplete the reserves?

Second, the reserves are relatively few in number and subject to disruption by bombing or terrorist attacks.

Third, dependence on the reserves does not protect the United States and the free world from OPEC-type market minipulations over the longer term.

On the other hand, coal has the ability to alleviate each of these concerns. Our supplies are virtually unlimited for the duration of even extended international crisis; the industry is diffused throughout the country and is not apt to be completely crippled by terrorist or nonnuclear attack; and the increased dependence on coal for free world energy needs reduces the potential effects of deliberate manipulation of the oil market.

From a different perspective, I believe the inclusion of coal in our international affairs has the potential to contribute greatly to international political stability.

Indeed, our dealing with the lesser developed countries, the combination of energy and agricultural resources, may be far more important than sophisticated military weapons.

As a corollary to this concern, I call your attention to the importance of developing and maintaining a manpower base for all phases of coal research and development.

Our experience of the early 1970's in initiating research under the Coal Mine Health and Safety Act and for appropriations in response to the 1973 oil embargo, vividly demonstrated our weakness in this area.

We met the challenge by redirecting the careers of doctoral students and recent graduates. Only after 10 years are we beginning to realize the benefits of growing our own generation of dedicated coal researchers.

It is imperative for our nation to continue this manpower development. This can only be done at universities, such as the one I represent. Moreover, it is our graduates that are the most effective channel of technology transfer from Government-sponsored research to industrial application.

It is for all of these reasons that I believe that the Federal Government not only has a role in all aspects of coal research, but also has a responsibility to assure the value of this energy source is developed and used to its fullest, domestically and internationally.

[The prepared statement of Dr. Aldridge follows:]

STATEMENT OF M. DAYNE ALDRIDGE, DIRECTOR, ENERGY RESEARCH CENTER, WEST VIRGINIA UNIVERSITY

My name is Dayne Aldridge. I am Director of the West Virginia University Energy Research Center and Professor of Electrical Engineering. For the past 13 years I have conducted research on coal mine safety and productivity and more recently I have been coordinating a $15 million energy research program which involves a wide range of coal related subjects. I also serve as a member of the West Virginia Coal Development Authority.

I want to thank you for this opportunity to appear here today. The hearings you have previously held on Coal Research have provided information on several different topics. I want to stress the importance of recognizing that the subject of Coal Research does cover a wide range of subjects—exploration, extraction, cleaning, transportation, liquefaction, and gasification. Other topics such as occupational safety and health, productivity and environmental protection cuts across all of these.

Today I will limit my comments to three major points--each of which, I believe, are critical to a federally sponsored program for Coal Research. Moreover, I believe each of these points have never been adequately emphasized and, in some cases, are not presently recognized as factors in our national energy research program.

1. Exploratory or basic research is important to all aspects of coal related technology.

I want to emphasize the word "all" because you have heard in previous testimony about the importance of our understanding the basic chemical and physical properties of coal and the reactions involved in conversion and cleaning processes. I want to not only affirm this fact, but also to emphasize the critical importance of a strong exploratory research effort as a foundation to each applied area of coal research. In my opinion, this has been one of the short comings of the DOE Fossil Energy Program and, historically, has been a problem with coal research in this country. True innovation in the applied areas must evolve from exploratory and basic research activities. The more fundamental discoveries are the "seed corn" for advances in the real world of production.

While it is true that currently known coal conversion technologies are not economically competitive with imported liquids, it would take only one fundamental discovery to change that balance. Similarly, the knowledge base we apply to exploration, extraction, cleaning, transportation or combustion of coal could be transformed through fundamental scientific and engineering breakthroughs.

It deeply disturbes me that we seem to have lost faith in mankind's ability to innovate and to discover. Too often, government sponsored applied research programs require that the "breakthrough" be almost certain before the "research" funds are awarded. This isn't research. It's a marketing game of "pay me for the solution now that I found it". This attempt at reducing the "risk" of government funded research has led us to bankruptcy in many applied research areas. Without "seed corn" the farm ceases to produce. Ladies and gentlemen, I believed we may have arrived at this situation in some coal research areas such as the one I will discuss next.

2. Underground coal extraction research should be a high priority topic in our national energy program.

It is not.

Of our 475 thousand million tons of total minable reserves, 67% is expected to be mined by underground methods. Of the eastern reserves that are most likely to provide for export to the European market, 80% is expected to come from underground mines. As the easier to acquire coals are depleted, much of which will come from surface mines, we will be forced to deal with deeper and thinner seams that will be more expensive and possibly less safe to mine than possible with present technology.

The United States has been described as the Saudia Arabia of coal. This has inferred to many that we can "automatically" expect to play a commanding role in the future world energy market, especially as we compete with other producers of coal. Ladies and gentlemen, we do not have a monopoly on coal. There are many competitive forces at work in the world coal market. Today we do not deliver the least expensive coals to Europe. Their buyers say that our coal exports have remained high, despite uncompetitive prices, simply to assure reliability of supplies. The virtual monopoly of Australia, South Africa and the United States is now being broken by Poland's reentry to the marketplace and will be further erroded in the future by the People's Republic of China and Botswana as well as others.

We must plan now to assure our long term competitiveness in the world coal market. The technology we apply to the underground mining of coal at the turn of this century will play a key role in our position in the international energy arena. Today there is no federal commitment to meeting this long term need. Some will argue that there are no innovations on the horizon to dramatically affect underground productivity and thus, a major coal mining research and development program is unlikely to produce worthwhile results. I submit that this is true--because we have had essentially no investment in exploratory research in this arena. There is no "seed corn" so the farm can't produce.

Others will argue that such research is the responsibility of the mining industry, especially the manufacturers of mining equipment. While they do have a research role to play I call two factors to your attention.

First our mining industry is highly fragmented. The long term competitive edge for a mining company comes from good systems engineering--the efficient use of an array of devices and apparatus which are generally available to all miners of coal. Component innovation is left largely to the manufacturer and, thus, is available to all users.

The second factor is the international nature of the mining equipment market. United States manufacturers must compete with foreign entities who enjoy government sponsored research and development in arrangements where the laboratories and mines are government owned or subsidized. This has led to countries such as the United Kingdom, Germany and France developing and exporting new mining technology to the United States.

Thus, I strongly advocate a high priority for exploratory research related to the underground extraction of coal with the broad objective of meeting our long term needs.

The third point I wish to raise relates to the topics I have just been discussing. However, it has much broader implications than just coal mining. It relates to our whole coal research and development strategy.

3. Coal should be a key factor in our long term planning for national security and international stability.

Given the events of the past ten years and the demonstrated importance of energy resources in international affairs, I cannot understand the current lack of attention for coal in the formulation of international policy and military planning.

The current strategy of depending primarily on the Strategic Petroleum Reserve to offset the disruption of oil imports has implications which greatly concern me. First, this strategy is predicated on the assumption that disruptions will be short term in nature. What is the second line of defense if conflicts should be sufficiently long to deplete the reserves? Secondly, the reserves are relatively few in number and subject to disruption by bombing or terrorist attacks. Thirdly, dependence on the reserves does not protect the United States and the free world from OPEC-type market manipulations over the longer term. On the other hand, coal has the ability to aleviate each of these concerns. Our supplies are virtually unlimited for the duration of even extended international crisis; the industry is diffused throughout the country and is not apt to be completely crippled by terroists or non-nuclear attacks; and, the increased dependence on coal for free world energy needs reduces the potential effects of deliberate manipulations of the oil market.

From a different perspective, I believe, the proper inclusion of coal in our international affairs has the potential to contribute greatly to international political stability. Indeed, in our dealing with the lesser developed countries the combination of our energy and agricultural resources may be far more important than sophisticated military weapons.

As a corollary to this concern, I call your attention to the importance of developing and maintaining a manpower base for all phases of coal research and development. Our experience of the early seventies of initiating research under the Coal Mine Health and Safety Act and for appropriations in response to the 1973 oil embargo, vividly demonstrated our weakness in this area. We met the challenge by redirecting the careers of doctoral students and recent graduates. Only after ten years are we beginning to realize the benefits of growing our own generation of dedicated coal researchers. It is imperative for our nation to continue this manpower development. This can only be done at Universities such as the one I represent. Moreover, it is our graduates that are the most effective channel of technology transfer from government sponsored research to industrial application.

It is for all of these reasons that I believe that the federal government not only has a role in all aspects of coal research, but also has a responsibility to assure the value of this energy source is developed and used to its fullest--domestically and internationally.

Mr. Fuqua. Thank you very much, Dr. Aldridge, and all of our witnesses, I think we have touched on some very important points.

Dr. Aldridge, you mentioned about basic research for coal was not sufficient, or insufficient, I guess, now about DOE.

Does not DOE have facilities in Morgantown and at Pittsburgh that they are doing work in deep coal extraction, plus some basic research that is going on at those two facilities?

Dr. Aldridge. I didn't mean to imply that DOE does not sponsor fundamental research.

Mr. Fuqua. No, I didn't gather that, but I got the impression you felt like it was inadequate.

Dr. Aldridge. Yes, and in particular, I think the point that I am trying to drive home today is how it relates to the extraction of coal. It has been wholly inadequate. In fact, from what I can tell, it is essentially nonexistent and from a university that has had a lot of research sponsored by the State of West Virginia as well as through the Mine Health and Safety Act of 1969, it has been very frustrating to find ourselves dealing with technology that be applied only to safety concerns. For example, we see that same technology could be applied to extraction for improving productivity, et cetera, and we were not able to do that because the previous program did not permit the more fundamental kinds of developments to be explored, those with the longer term kind of applications.

Mr. Fuqua. Dr. Davis, you were talking about the electron beam devices and that they could remove the ash prior to combustion.

Could you elaborate on that some?

Dr. Davis. The treatment of the flue gas is after combustion with the present electron beam processes. Two processes are involved. One of them, the one we are working on, is in the research phase, namely the question of removal of coal fly ash, after combustion.

The other process is the removal of SO_2 and NO_X by electron beam treatment. There are two projects in that area, the one at AVCO/EBARA and the other is at Research Cottrell. Those two projects are ready for scale-up test and DOE participation is planned.

Mr. Fuqua. We discussed this briefly in the previous panel and I think you were in the room at that time, what is—maybe all three of you, Dr. Kessler, coming from industry, what is the proper role for universities in coal research?

Dr. Davis. A point which has been mentioned several times before will bear reiteration. Support of basic research in coal physics and coal chemistry areas. This is absolutely essential because that is where the new foundations are laid for new technologies. When this research is carried out with vigor and excitement, the ferment necessary for invention and new technologies is generated.

University research is the training area for those people who will serve in several roles: future managers for plants, future scientists and engineers to carry forward results of research to confirm technical applications and then bring this into industrial utilization.

Dr. Aldridge. I would like to confirm that statement from our own personal experience in the area that relates to coal mine health and safety. Prior to 1969, there was virtually no research going on in that area.

Mr. Fuqua. I was just going to point out that I think we almost went through what is comparable to the Chinese cultural revolution in coal research. After World War II, the emphasis was to get on oil and get off coal, it was filthy, and I think we did go through a cultural revolution where it was not in vogue to be doing any work in coal, and then after 1973, we suddenly realized that, hey, maybe this was not so good after all. We better get back to coal. And it has probably been even since 1974 that a renewed emphasis has been placed on the value of coal.

Dr. ALDRIDGE. We found in our experience that we began, even at our university, which has maintained a commitment in this area, despite the national policies and so on over the years, that the people were not there, that the people were not interested because they felt that, you know, it was not a national priority.

The thing that has been impressive to us is that as we have trained the Ph. D.'s in the research effort, this gets back into the classroom, to the undergraduate, and it is our graduates in various engineering programs, for example, that go out and work for the mining companies and for the users of coal that introduce the new technology, that bring on the new ideas.

I think that is one of the unique roles that the universities have to play and industry cannot provide that, although industry can do good research, both basic and applied.

The universities have a role that no one else can perform, that is bringing up the new generation of researchers and practitioners that take that technology out of the mine.

Mr. FUQUA. Dr. Kessler, do you have anything?

Dr. KESSLER. I would basically support those remarks. Universities have a very large role in basic coal research and science and the only role in developing the practitioners of it.

I believe industry can play some role in basic coal research but probably its main role will be in the development of new processes which it will bring to market.

Mr. FUQUA. We have also discussed in the previous panel the role of national laboratories' involvement, whether it be through the universities or the national labs and industry.

What would be your thoughts along those lines?

Dr. KESSLER. I would say that the role of the national laboratories is probably in the area of basic coal research but I believe that the major part of that role is better played by universities.

As was mentioned, they have the main—the only role in the development of new practitioners and they do have better ties, in general, with industry, to which these processes will eventually be transferred.

Mr. FUQUA. Dr. Kessler, you mentioned about the role of MHD in increasing the coal-fired plant efficiencies and so forth.

How much additional research is necessary to fully define the MHD process?

Dr. KESSLER. I don't believe any additional research is necessary to define the MHD process. I believe the MHD process has moved to a point at which we can think about constructing pilot plants. In fact, as you are probably aware, the Russians are in the process of doing just that, and hope to have one on line by 1985 or 1986.

In connection with MHD, I would like to mention the large number of spinoffs that have been produced. The main advantage to MHD was, of course, the development of high-efficiency electrical energy conversion.

This has required development of slag-rejecting coal combusters, and now we find that such coal combusters may have great potential in retrofitting oil- and gas-fired boilers which cannot tolerate contamination by large amounts of slag, and coal ash.

It is MHD technology, or technology spun off from MHD, which provides a means of getting rid of that coal ash before it gets into the boiler and offers a combuster which can be used to retrofit existing boilers.

That is a very good example of a federally supported R&D program which has achieved not only its own ends, but has also spun off technology that can be very valuable in other areas.

Another spinoff from MHD is the development of slagging wall technology. Various coal gasification and combustion processes require high energy density in which the heat has to be contained in a small volume. One solution to that would be to put refractory on the walls, but the refractories are usually severely eroded after a while.

We have found, through MHD technology, a way to coat walls with slag, which forms a self-replenishing coating. This is a very useful technique for use in combusters and gasifiers.

Mr. FUQUA. Do you think the Federal Government has an appropriate role in funding two test facilities for MHD? Or should it be narrowed to one?

Dr. KESSLER. I believe the two test facilities you are speaking of, the one in Montana and the one in Tennessee, have very different roles. The one in Montana has the role of integrated testing of the topping cycle, which is the MHD flow train, the combuster and the channel, the magnet, the electrical controls, and that is where it stops.

Another large part of the MHD process is the downstream equipment. After the working gas flows through the topping cycle, it flows through the boiler including gas-cleaning and the steam generation processes, and the seed regeneration section.

That is the role of the other test facility in Tennessee. So I believe both test facilities should be supported, as both are needed to develop a viable MHD process.

Mr. FUQUA. The direct decomposition of coal, what does that mean in your testimony?

Dr. KESSLER. I believe we were referring to observations we had made on the value of high heating rates to produce gases from coal more rapidly and in greater quantity than with lower heating rate, and in predicting reactions which occur between gases rather than between gases and solids.

Mr. FUQUA. Dr. Davis, you mentioned you were a member of the American Physical Society study group on coal utilization and synthetic fuel production.

What was the group's high-priority recommendation for coal research?

Dr. DAVIS. There were several areas mentioned in the summary——

Mr. FUQUA. What do you consider most important?

Dr. **Davis**. The area I would personally consider most important is the physics of small particles and especially surface of the small particles. In fact, one could call this by a term which is gaining scientific popularity, aerosol physics.

Mr. **Fuqua**. Coal, then.

Dr. **Davis**. Fine particles are involved in all uses of coal and at various stages in each process. It starts with grinding. The coal particles are then either burned in combustion or subjected to process treatment in either gasification or liquefaction systems. At the other end are the products which are usually particles.

The prevalence of particles is equally true in fluidized bed combustion. If their is one particular area for research which has close relationships with all coal utilization processes, I would say it is the physics of small particles.

Mr. Gannon, do you have anything to elaborate on?

Mr. **Gannon**. No, I think you have asked the questions and we have tried to reply.

Mr. **Fuqua**. Thank you. We want to thank all of you for being here today and we appreciate the contributions that you have made to something that we have been very interested in. As some of the panelists on the first panel mentioned I think it is generally felt by the committee that we need a proper mix, not that coal is the total answer, not that nuclear is the total answer, or renewables are the total answer. We need some of all of it.

We have been very much concerned, particularly with the impact that the fossil budget has had in the recent budget cycles, and an emphasis maybe tilted away from a balance. It has caused a great deal of concern. The proper role of the Federal Government in the involvement of basic and applied research is that we can take those things from the laboratory and demonstrate them and find out how we can best utilize them.

So I thank you all very much for being here, both this panel and those who were members of the first panel.

Thank you very much.

[Whereupon, at 11:18 a.m, the subcommittee was adjourned.]

APPENDIX

INFORMATION FOR THE RECORD

ENERGY TOPICS
A Periodic Supplement to IGT HIGHLIGHTS

October 1, 1979

NOTE FROM THE EDITOR: *Discussions of the impact of increased U.S. oil imports have generally focussed only on their direct costs. The following article represents an initial attempt to quantify some of the* external *costs associated with imports, particularly their effects on inflation, unemployment, and national security. While not intended as the final word on the subject, this article will, we hope, serve to stimulate further studies in this important area.*

THE DIRECT AND EXTERNAL BENEFITS OF REDUCING OIL IMPORTS

The United States increased its imports of crude oil from 4.7 million bbl/day in 1972 to about 8.7 million bbl/day in 1977. Despite a slower rate of growth in total energy demand, these large oil imports have been needed because some energy prices have been kept below market-clearing levels, domestic oil and natural gas production have decreased, nuclear and the direct use of coal have encountered environmental delays and costs, and the cost of new energy technologies has been higher than the short-term direct cost of oil imports.

The increase in oil imports has been accompanied by a dramatic rise in cost from $4.3 billion in 1972 to $41.5 billion in 1977 and to an estimated $60 billion in 1979, as shown in Table 1. These costs may best be shown as the percentage of our exports (goods and services) that is needed to pay for imported oil — a figure that has increased sharply from 4.3% in 1970 to 24.6% in 1979.[*] Such large costs raise the question of whether an energy policy based on high oil imports is cost-effective; that is, has the reliance upon imports provided consumers and the nation with the lowest cost energy? This study goes beyond direct cost comparisons of oil imports with new domestic energy supplies to calculate initial quantitative estimates of the externalities (indirect costs) that are associated with large oil imports. Public policy, if it is economically sound, must be based on encouraging the lowest *total* (i.e., social) cost energy sources.

Table 1. SALIENT CHARACTERISTICS OF OIL IMPORTS: 1970-1979

Year	Crude Oil and Refined Petroleum Products Imports, 10^6 bbl/day	Net Energy Imports as Percentage of Total Energy	Cost of Oil Imports, $\$10^9$	Cost of Oil Imports as Percentage of Total Exports
1970	3.0	10.1	2.8	4.3
1971	3.8	12.4	3.3	4.8
1972	4.7	15.6	4.3	5.6
1973	6.3	17.0	7.6	6.9
1974	6.1	16.7	24.3	16.6
1975	6.0	18.6	24.8	15.9
1976	7.3	19.5	31.8	18.6
1977	8.7	23.5	41.5	22.7
1978	8.2	21.7	39.1	17.9
1979*	8.5	24.7	60.0	24.6

Data Source: U.S. Department of Energy, Monthly Energy Review and the U.S. Department of Commerce, *Survey of Current Business*.

* Preliminary

Although today we know more about the externalities of oil imports and recognize the biases associated with selecting fuels simply on the basis of their direct costs, the specific dollar per barrel range of the externalities is not known. Whether these externalities are large enough to justify a program to become independent from the Organization of Petroleum Exporting Countries (OPEC) or to subsidize the development of synthetic fuels is the subject of this study, which analyzes the major externalities associated with decreasing oil imports by 500,000 bbl/day. We assume that decreased oil imports are replaced either by increased domestic energy supplies, such as synthetic fuels, or by conservation. However, the costs of these replacements are not analyzed in this paper. There are several alternative ways of conceptualizing the externalities of replacing oil imports. This study adds these externalities to the direct costs of oil imports. This total cost of imported oil is then compared with the direct costs of new domestic energy supplies for tentative evaluation.[*] In the following analysis, the external benefits of reducing oil imports are real; however, they will fall as the direct cost of new U.S. energy supplies rises above the direct cost of imported oil. Some of the benefits from replacing oil imports remain until the direct cost of new U.S. energy supplies is greater than the total cost of imported oil, assuming that is, that the externalities not analyzed for both imports and new domestic supplies counterbalance.

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[*] Of course, besides indicating a possible energy problem, this ratio of oil imports to total exports suggests an export problem. Both Japan and the Federal Republic of Germany have reduced their ratio of oil imports to total exports.

[*] Further analysis is still needed to add the externalities not examined here to both oil imports and domestic energy supplies. These externalities include environmental costs, regulation costs, taxes and subsidies, and health costs. An alternative conceptual framework would be to treat some of the externalities such as increased domestic employment as benefits of increasing domestic energy supply instead of reduced oil imports. In this framework, the benefits could be subtracted from the direct cost of new domestic energy costs instead of being added to the cost of oil imports. Either framework yields the same conclusions.

When a cost or benefit is incurred by someone other than the producer or buyer, it occurs outside of the market transaction and is thus called an externality. An external cost occurs when part of the cost of producing or using a good must be paid by someone other than the firm that produced it or the individual who consumed it. Thus, prices do not always reflect *all* the costs incurred in producing or using a good. As a result, resources are allocated to goods that would not be demanded in such large quantities if the true costs were reflected in their prices. The general rule is that externalities cause free pricing or direct cost comparisons to be nonoptimal. For example, manufacturers poured smoke relatively freely into the air when they did not have to pay the cost of environmental clean-up. Externalities create a *prima facie* case for institutional change, either to set standards to end the externalities or to set payments on the market transaction such that those who incur external costs are compensated or those who incur external benefits contribute to the market transaction.

In the last decade, the United States passed a series of environmental protection laws, with the result that some of the external costs are now part of the firm's production costs and as such are reflected in the market price or the direct costs. For example, the price of coal from strip mines now includes a charge to cover land reclamation costs. Land reclamation has been made part of the firm's cost by public policy; the externalities, in the language of the economist, have been internalized. For many new energy technologies, such as substitute natural gas (SNG) from coal, many of the externalities associated with air, water, or land pollution have been made part of the production costs. Thus, the United States has seen the direct costs of these energy sources rise rapidly while the external costs have largely disappeared.

The consumer of imported oil, however, is largely spared the external costs and does not feel them when he makes his market transaction. Thus, the cost of imported oil is lower than it would be if the cost reflected associated externalities of inflation, unemployment, and national risk. The resulting biased cost comparison leads the consumer to over-consume oil imports in much the same fashion as the manufacturer once polluted the air.

This study analyzes three categories of externalities associated with decreased oil imports: lower inflation through currency appreciation from improved trade balance and lower oil prices; increased real domestic output from fewer dollar leakages, and potential decreased supply disruption cost from less dependence on oil imports. The short-run effects of each of these externalities are developed in a series of partial equilibrium analyses.

Some Externalities of Oil Imports

Impact on Inflation

Increased oil imports have accelerated the inflation rate in the United States in several ways. First, the supply of and demand for oil is highly inelastic in the short run; thus, any incremental increase in demand or decrease in supply may result in much higher crude oil prices. Also, the prices of several U.S. energy sources move in tandem with imported oil prices. Further, larger oil imports may exacerbate balance-of-payment problems, which, other factors held constant, cause currency depreciation and higher domestic prices. Each of these factors not only raises the inflation rate, but once the inflation rate is increased, a set of secondary influences are set in motion which tend to raise it further. The reduction of oil imports would set in motion external benefits in the opposite direction.

Reducing demand for OPEC oil not only involves direct cost savings but may also result in lower prices than would otherwise have existed for the oil that is still being imported. The extent of price adjustment due to a shift in demand depends upon behavioral assumptions about how OPEC administers oil prices. In the past, OPEC's pricing policies have reflected market realities. The spot market for oil is competitive, and this market signaled OPEC's price increases both in the 1973-1974 period and in 1979. This market also signaled the inappropriateness of price increases in the 1975-78 period.

To compute the short-term effect on oil prices of a 500,000 bbl/day decrease in demand, a price elasticity of demand of −0.13[*] and a price elasticity of supply of 0.25[†] were assumed. Given these assumptions, the effect of a 500,000 bbl/day decrease in imports is a $0.52/bbl drop in price. Prices in most price-administered markets tend to be inflexible. This rigidity is enhanced by the existence of OPEC, especially Saudi Arabia, which can be expected to reduce output in the near term if the United States reduces its oil imports. Thus the near-term supply relation was chosen to evaluate the short term. This study assumed that OPEC would reduce the quantity supplied by about 325,000 bbl/day. The benchmark OPEC price may not change but surcharges would be cut or discounts given by some oil exporters such that the average price would fall $0.52/bbl over a two-year period.[‡]

[*] Short-term elasticities generally are estimated to range between −0.07 and −0.61 depending upon methodology, economic sector, and petroleum product. The −0.13 price elasticity is a short-term consensus estimate of prior empirical analyses found in James A. Edmonds, *A Guide to Price Elasticity of Demand for Energy Studies and Methodologies*, Institute for Energy Analysis, Oak Ridge, Tennessee, 21-22 (1978) August. The application of these elasticities to future periods where prices are far above the levels in the original estimate should be interpreted with caution.

[†] Estimates of world and OPEC oil supply elasticities are highly uncertain due to the political and geological unknowns. This uncertainty precludes the use of supply elasticities as a final arbiter in forecasting price adjustments due to a demand shift. Short-term (1 to 3 years) price elasticity may be virtually equal to zero. OPEC's supply curve may be backward-bending, since at higher prices the OPEC nations are more inclined to cut production until a period arrives when they need revenues. Counter-balancing OPEC's supply is increased production from the rest of the world. In the near term, this supply elasticity may equal +0.25 and in the long term +0.7. This study uses near-term elasticity to evaluate the likely short-term impact of our scenario, since assuming a supply elasticity of zero gave extreme estimates of the external benefits of reducing imports.

[‡] This estimate may be conservative. Given the tight world oil market, the marginal impact of a 500,000 bbl/day change in demand is great. The price adjustment was calculated from a price of $23.50/bbl and world oil consumption of 60.1×10^6 bbl/day, which are assumed for a current equilibrium position. Given the price elasticity of demand of −0.13, equilibrium at $23.50/bbl, and 60.1×10^6 bbl/day, consumption, a 500,000 bbl/day decrease in demand will cause the price to fall 6.426% if there is no change in supply. Elasticity is defined as the $(\Delta Q/Q)/(\Delta P/P)$. Likewise, given a supply elasticity of 0.25, this reduction in price would cause a 1.61% decrease in the quantity supplied. To solve for the new price-quantity equilibrium, the demand and supply curves were estimated as $Q_d = 67.88 - 0.331P$ and $Q_s = 45.07 + 0.64P$. These relations are valid only for small changes from the original equilibrium position. Then demand was decreased by 500,000 bbl/day or $Q_d = 67.38 - 0.331P$. The new equilibrium price is $22.98 or a change of $0.52/bbl due to the reduction in U.S. oil import demand.

This lower price affects all imports into the United States as well as domestic petroleum production which is uncontrolled (approximately 30% of total U.S. output). Thus, in the first year, the computation of the external benefits is based upon the remaining 7.93 million bbl/day of imported crude oil and refined petroleum products plus 30% of the 8.41 million bbl/day domestic crude production. This quantity, 10.45 million bbl/day, is multiplied by the $0.39/bbl lower price (which is three-fourths of the total effect identified). The first-year external benefits amount to a savings of $4.08 million/day. In the second year, we assumed the full $0.52/bbl price effect and the deregulation of one-third of the price-controlled domestic oil production. However, due to an assumed 60% windfall profit tax, society captures only 40% of the lower price on this uncontrolled oil as an additional external benefit. Thus, the external benefit in the second year is $0.52/bbl times the sum of 7.93 million bbl/day of imports and 3.31 million bbl/day of domestic oil or $5.84 million/day. The 3.31 million bbl/day of domestic oil was calculated by multiplying total domestic production of 8.41 million bbl/day times the sum of 30% plus 70% times 33.3% times 40%. In the third year, an additional one-third of the original price-controlled domestic oil is decontrolled. Thus, the external benefit is equal to $0.52/bbl [7.93 + 8.41 (0.30 + 0.70 × 0.667 × 0.40)] million bbl/day or $6.25 million/day. Expressing these external benefits on a per barrel basis for the 500,000 bbl/day reduction results in $8.16/bbl, $11.69/bbl, and $12.50/bbl for years one through three.

Decreasing oil import costs through lower prices or decreased quantities also has an immediate effect upon the U.S. balance of trade.[*] Holding other factors constant, the trade balance improves. The linkage between the trade deficit and domestic inflation is a result of the flexible exchange rate system begun in the 1971-73 period and the high price inelasticity of many items traded.[†]

The United States enjoyed a favorable balance of trade from World War II through 1970. Since 1970, it has largely been unfavorable. The U.S. oil import imbalance has grown greatly since the early 1970's and although the $45 to $60 billion cost of oil imports is extremely large, oil imports still represent less than 25% of total imports. Thus, our trade deficits are not solely due to oil imports.[‡]

Balance-of-trade deficits can be offset by the large net investment income which the United States historically receives. However, travel, remittance, military, and transfer outflows have more than offset investment income, so that since 1970, the U.S. current account has been in deficit every year except 1975. The existence of financial markets allows several degrees of freedom; for example, capital inflows to the U.S. offset the current-account deficit. Foreign holders of U.S. dollars may choose to buy U.S. equity, hold U.S. private and public debt, and deposit these dollars in their accounts within the United States. However, a close correlation has existed between the current-account balance and exchange rate movements.[a] Chase Econometrics has estimated that for every $10 billion improvement in the U.S. trade balance, a 5% improvement in the trade-weighted value of the U.S. dollar occurs.[b]

Flexible exchange rates were traditionally viewed as a self-correcting device for a balance-of-payments deficit or surplus without greatly affecting the rate of inflation. If the United States ran a current-account deficit which was not offset by reversed net capital flows, foreign entities would be holding more U.S. dollars than they desired. This supply-demand imbalance would be corrected by a depreciation of the U.S. dollar. This depreciation would lower the price of U.S. goods in world markets, inducing increased U.S. exports, while foreign goods would become more expensive in the United States, leading to lower U.S. imports. The U.S. trade or current-account deficit would move into balance.

Recent experience suggests this traditional viewpoint of the adjustment process needs modification.[c] Price fluctuations occur long before there is a perceptible change in quantity flows. Our patterns of consumption and production change slowly. Thus, depreciation may widen, not narrow, the balance-of-payments deficit in the short term; a greater deficit indicates an even further currency depreciation.[d] The reverse will be occurring in the trade surplus country. Thus, we can observe in Italy a four-year period (1973 to 1976) when its currency was depreciating and its balance of payments stayed negative; in Germany balance-of-payment surpluses every year since 1971 and an upward appreciation of its currency; and, in the United States, a widening deficit since 1976 and a depreciating currency. The equilibrating process appears slow at best. Dornbusch and Krugman in an analysis of the adjustment process conclude that "there is a significant price responsiveness due to exchange rate movements, but the adjustment lags in the quantity of exports and imports are important and run in years, not quarters. . . ."[e]

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[*] The three major balances in international transactions are the balance of trade, which measures merchandise exports and imports; the current account, which adds to the balance of trade investment income and services (military, transfers, travels, and remittances); and the balance of payments, which adds to the current account the capital account of short- and long-term capital flows and government interventions in the currency market.

[†] Given the circular flows among the interrelations, all these factors are correlated. The flexible exchange rate system is itself a function of prior trade and balance of payments problems, which were caused by multiple factors including relative inflation, money supply growth rates, and international political policies.

[‡] The Federal Republic of Germany and Japan are examples of countries which have greater dependence on imported oil than the United States, but have yet had balance of trade surpluses in the recent period. This reflects the increased competitiveness of each country in the export sector plus their low rates of inflation and monetary growth.

[a] In markets, once exchange rates adjustments are anticipated, speculators often take advantage of this expectation withthe result that the relationship between the current account and the U.S. exchange rate assumes random characteristics. While the data base under floating exchange rates is limited to the 1973 to 1978 period and does not permit a highly reliable estimate, a clear relation does appear to exist.

[b] John C. Zamzow, "The Economic Impact of Oil Decontrol," *Testimony Before Energy Subcommittee of Joint Economic Committee*, 9 (1978) April.

[c] Arthur Laffer has argued that the new environment is also due to a reduction in trade barriers, and that improvements in international transportation and communication have put domestic markets in close contact with each other, allowing the international market to approach the conditions of an efficient market. Arthur Laffer, "The Bitter Fruits of Devaluation," *Wall Street Journal*, (1974) January 10.

[d] John Bilson, "The Vicious Circle Hypothesis," *International Monetary Fund Staff Paper*, 2 (1979) March.

[e] Robert Dornbusch and K. Krugman, "Flexible Exchange Rates in the Short-Run," *Brookings Papers on Economic Activity*, 3, 537-75 (1976).

Exchange rate depreciation adds to the country's rate of inflation by raising the price of imported goods, the price of domestic goods with imported inputs, and the price of domestic goods and inputs which were competitively priced with foreign goods and inputs. Because laborers in a modern inflationary environment have won either formal or informal cost-of-living adjustments, these higher rates of inflation lead to higher wages and further price increases as the higher labor costs are passed on. Further, the money supply of the depreciating country may be expanded in order to accommodate the higher prices and also because depreciation may signal some ability of the economy to be stimulated.[*] A vicious circle develops. The currency depreciation brings even greater inflation and further depreciation. The country with a trade surplus and currency appreciation experiences what has been called a "virtuous" circle. Appreciation leads to lower inflation rates which lead in turn to increased trade competitiveness in the export market and further trade surpluses. In the long run, expenditure switching to the depreciated cheaper good increases the exports of the deficit country, bringing equilibrium. However, the costs incurred before equilibrium is attained are substantial.

Hooper and Lowry in an analytical survey of the impact of currency fluctuation and changes in domestic rates of inflation developed a consensus estimate that a 10% dollar depreciation on a multilateral weighted average basis will raise the consumer price level by 1.75%.[†] Of this increase in inflation, 1% is felt the first year, and the remaining 0.75% in the second year.

Using these relationships with respect to this study's specific scenario of reducing oil imports by 500,000 bbl/day, the total cost of oil imports (assuming an average cost of $20/bbl) falls $3.65 billion in the first year ($20/bbl × 500,000 bbl/day × 365 days) because of fewer imports and $1.13 billion ($0.39 × 7.93 million bbl/day × 365 days) because of their lower price, yielding a total saving of $4.78 billion.[‡] The United States can expect its exports of goods and services to fall $0.235 for each one dollar reduction in its oil imports. Also, if the $4.78 billion remains in the United States, imports of other goods and services will tend to increase by $0.14 for each $1 of reduced oil imports. (These relationships are discussed further in the following section.) Thus, the 500,000 bbl/day reduction in oil imports will tend to cause a $2.99 billion improvement in the U.S. trade balance. This improved trade balance causes a 1.49% improvement in the value of the dollar based on the Chase Econometrics relation which in turn lowers the rate of inflation by 0.149 percentage points in the first year, based on Hooper and Lowry. In the second year, the rate of inflation falls by 0.275 due to an additional 0.112 as the remaining impact of Year-1 trade improvement plus an additional 0.012 due to the full $0.52/bbl price effect on oil imports ($0.13 × 7.93 × 365 × 0.625 = $236 million trade improvement = 0.118% improvement in the value of the dollar = 0.012 reduction in the rate of inflation) and an additional 0.002 due to the increase in the real price of oil imports ($0.40 × 0.5 × 365 × 0.625 = $46 million = 0.023% = 0.002 reduction in the rate of inflation). Finally, in the third year, the rate of inflation falls by 0.288. This is the result of an additional 0.011 decrease due to the remaining impact of the latter two improvements in Year 2 and an additional 0.002 due to another increase in the real price of oil imports that would have occurred. Translating this lower inflation rate into a $/bbl benefit is subject to many caveats, and this study offers only a conservative estimate.

Gardner Ackley has argued that there are two broad kinds of costs of inflation: redistribution in income and wealth that serve no economic purpose, and reductions in the level or rate of growth of production.[*] The latter occurs through the effects of accounting and taxes, effects upon aggregate demand, and effects on aggregate supply. The costs of inflation increase as the rate increases.

As individuals and firms learn to live with inflation, workers obtain cost-of-living adjustments (COLA's) in their contracts, business firms change their accounting procedures, the aged campaign for the indexing of social security and for higher passbook savings rates, and minimum wages are indexed to inflation. These COLA's as well as altered business accounting procedures may have increased the cost of inflation. Such increased costs arise from the fact that COLA's tend to force any inflation rate even higher and to narrow the population, individuals, and firms who feel the burden of the higher prices.

Another avenue in assessing the costs of inflation involves the short-run trade-off in public policy between unemployment and inflation.[†] The United States has at times been willing to see the costs of unemployment rise in order to lower the rate of inflation. In recent years, higher inflation rates have been associated with higher unemployment, making us aware of the second cost of inflation identified by Ackley. The rate of inflation was a precipitating factor in the 1974 recession.

In the mid-1960's, Arthur Okun, who was then chairman of the Council of Economic Advisers, developed a discomfort index which purported to measure the level of economic well-being. Two equally weighted factors make up this index — the unemployment rate and the rate of inflation. A 1% increase in the portion of the labor force out of work increased the discomfort index by 1 unit as did a rise of 1% in the rate of inflation. Since the mid-1960's structural changes have occurred in both the make-up of the labor force our ability to adjust to inflation, and our expectations about inflation.

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[*] Marcel Collin *et al.*, "The Possible Effects of Exchange Rates Upon Domestic Price Levels," *Business Economist* 57-62 (1978) May.

[†] Peter Hooper and Barbara Lowry, "Impact of the Dollar Depreciation of the U.S. Price Level: An Analytical Survey of Empirical Estimates," *International Finance Dicussion Papers*, No. 128 (1979) January. This impact assumes that oil prices are raised to affect U.S. dollar depreciation and that public policy attempts to maintain its GNP target.

[‡] The immediate effect of decreasing oil U.S. imports is the smaller trade deficit. This improves the value of the U.S. dollar, which raises the price of oil to other importing countries. Oil prices tend to soften within a year and additional trade improvement occurs. However, the effect of this last $1.26 billion is uncertain. As oil prices fall, all oil importers experience lower oil import costs unless their currencies lose value relative to the U.S. dollar. U.S. dollar appreciation relative to the stronger currencies (e.g., mark, yen, Swiss franc) is likely as the improved balance-of-payment position of the United States lessens speculation that the long-term trend of the U.S. dollar is downward. This posited narrowing of the discount on the U.S. dollar versus stronger currencies is analogous to the narrowing of the spread in bond yields between differing qualities in prosperous periods. Thus, the lowering of oil prices will cause additional appreciation of the U.S. dollar and lower inflation rates. Mike Barren posits a different scenario in "The Import Premium: The Benefits of Reduced U.S. Oil Demand," draft paper, DOE, Office of Oil and Gas Policy (1979) July 20.

[*] Gardner Ackley, "The Costs of Inflation," *American Economic Review*, 149-54 (1978) May.

[†] In the longer period, inflationary expections adjust to equal the actual rate of inflation and invalidate the short-run tradeoff between unemployment and inflation. A continual increase in the rate of inflation faster than the rate anticipated is needed for the inverse relation to hold. However, with imperfect resource mobility and knowledge, and without a firm basis for specifying the level of anticipated inflation, the level of inflation is used to represent the cost.

The tendency of public policy is to be more responsive to the cost of unemployment than to inflation. Also, in a modern setting it takes more inflation before any one shock reaches equilibrium. Thus, this study will make an approximation that in general, 1% inflation has the same cost as 0.5% unemployment. This is very crude, and at times of high inflation and low unemployment this trade-off may understate the inflation cost while the opposite holds when inflation is low and unemployment is high.

In the following section on employment leakage, the cost of 1% more unemployment is estimated at $15.78 billion. Thus, the cost of 1% more inflation would be $7.89 billion.[*] The first year impact of this study's 500,000 bbl/day oil import reduction on inflation is $1.18 billion (7.89 × 0.149) or $6.44/bbl (1.18 billion ÷ 365 ÷ 500,000). In a comparable fashion, the benefit from a 0.275 lower inflation rate in the second year is $11.89/bbl and from a 0.288 reduction in inflation in the third year is $12.45/bbl.

Before proceeding to the remaining externalities, the reader should note that the externalities so far identified are largely unique to oil imports and the reasoning should not be applied to all imports. Our demand for oil imports as well as OPEC's supply curve are among the most inelastic of the goods we import. Also, the relationship between oil imports, trade deficits, and currency depreciation has unique properties. OPEC oil is priced in the world markets in terms of the U.S. dollar. Thus, U.S. reduction in oil import needs, although decreasing OPEC revenue directly, may increase OPEC revenue indirectly through the appreciation of the dollar with respect to other countries' currencies. An additional reason oil may be considered unique is that oil is a nonrenewable energy source and producing countries appear to desire to stretch its production over a longer period to encourage more even economic, social, and political development. Thus, U.S. action to cut 500,000 bbl/day from our current level of imports may be welcomed by OPEC.[†]

Analyses of the current U.S. trade-balance malaise often focus on a decline in U.S. competitiveness in world trade as well as on the large oil imports. An interconnection exists. If the United States were to decrease oil imports and the dollar appreciates, the U.S. inflation rate would subside. Further, because of the rising price of U.S. imports and OPEC oil, as the dollar appreciates, our trade partners would find their inflation rate increasing. The net effect of a U.S. curb on oil imports would be an increase in its competitive edge. At least some of the vicious circle would be shifted to our trading partners; some of the "virtuous" circle would lie in the United States. These unique properties of oil imports suggest benefits from the pursuit of a policy of decreasing imports of oil or, alternatively stated, developing an indigenous energy supply.

Employment Leakages

When the U.S. imports crude oil instead of consuming domestic energy, an outflow of income occurs. The amount of income lost from the use of foreign oil instead of the development of domestic supplies hinges on the marginal propensities to import and invest abroad in both the United States and the rest of the world.[*] When U.S. oil imports from OPEC are increased, OPEC has increased income, part of which returns both immediately and in later periods to the United States as new purchases and new investments. Further, OPEC increases its purchases from other countries and those countries then consume more U.S. output. In a Brookings Institution study, Robert Lawrence estimates that when all the secondary effects of each $1 spent on U.S. imports from OPEC countries are considered, $0.16 comes back as increased U.S. exports.[†] There would also be some additional OPEC purchases of U.S. services and additional non-OPEC purchases of U.S. services in secondary rounds. Assuming these services would rise in the same proportion as our recent mix of merchandise to services, then for each $1 the United States spends on imported oil, $0.235 comes back as increased United States exports of goods and services.[‡]

The replacement of oil imports with domestic energy supplies or conservation measures permits more dollars to be spent in the United States; however, part of this additional income generated in the United States will be spent on foreign goods and services. Recent national income data suggest that the tendency is for $0.11 of each additional dollar to be spent on imports of goods and for $0.03 to be spent on imports of services. Dollars are recycled not only through merchandise and services trade but also through the financial markets. Of each $1 spent on imported oil, approximately $0.12 comes back in the form of foreign direct investment in the United States, purchases of U.S. public and private debt, and demand deposits in U.S. banks after adjustments for interest and dividend payments. Conversely, if the United States had imported less energy, part of the additional domestic income generated would have gone into U.S. investment in foreign countries. The current propensity for this foreign investment, after adjustment, is $0.136 of each additional $1 income.

In the immediate time period, this study assumes that for each $1 gained by reducing oil imports, U.S. exports fall by $0.235, foreign investment in the United States falls by $0.12, purchases of foreign goods and services rise by $0.14, and U.S. foreign investments increase by $0.135; thus, $0.37 is available to stimulate the U.S. economy in the first period.[*] Through the multiplier process, these additional domestic expenditures will generate further increased income. The domestic multiplier is approximately 2.5.[†] Hence, over the near term, $0.93 of additional domestic income will be generated from each $1 shift from foreign to domestic energy.

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[*] The Council of Economic Advisers has estimated that the lump cost of a permanent increase of 1% in the inflation rate is $100 to $150 billion.

[†] U.S. action to cut imports of products from other countries may cause these countries to retaliate, thus generating additional costs to the United States in some other area.

[*] A multitude of other factors, of course, also influences the outflow, including monetary and fiscal policies, speed of recycling funds, and the market's anticipation as to whether these outflows are permanent.

[†] Robert Z. Lawrence, "An Analysis of the 1977 U.S. Trade Deficit," *Brookings Papers on Economic Activity*, No. 1, 163 (1978).

[‡] In the analysis here, these effects are treated as if they all occur within the first year. In reality, the secondary rounds may take 20 quarters before the complete effect is realized, although the effect occurs primarily in the earlier quarters.

Concomitant with the net dollar outflow is a net employment loss. This employment impact is seen in the multiplier analysis of incremental domestic energy development. As additional money remains in the United States, this money generates jobs and income. The income is largely domestically spent and generates incomes and jobs for others; this additional income is again largely spent domestically, generating additional incomes and jobs. The chain or multiplier effect does not, however, continue indefinitely as at each stage leakages occur.

The benefit in increased domestic employment from reducing oil imports by 500,000 bbl/day is best measured as either the number of jobs created or the additional real output which is produced. The latter measure can be expressed in dollars and hence directly combined with the other externalities; however, because part of the increase in gross national product (GNP) is used to buy old output at higher prices, the additional income generated from reduced oil imports is deflated by the average 1977-78 split between real output (39.4%) and price rise (60.6%). The reduction in oil imports was shown earlier to reduce the import bill by $4.78 billion in the first year. Given the leakages identified earlier in this section, only 37% of this reduced oil bill or $1.77 billion remains in the United States to stimulate employment.

During the 1960's and 1970's, 42,200 jobs were created for each $1 billion (1972$) additional spending. Thus, the immediate impact of reducing oil imports by 500,000 bbl/day (assuming a 69% increase in inflation since 1972) would be an increase of 44,200 jobs.[‡] Over a longer period, the multiplier process will expand this employment increase to 118,800. Alternatively stated, an increase of $1.77 billion in additional domestic demand will generate a $697 million increase in real output in the first year. In the second year, the multiplier effect in assumed to magnify this real output increase to $1.27 billion (3 years were assumed necessary for the full multiplier effect) plus in the second year there are additional effects from the full $0.52/bbl price impact and from the increased real price of oil. These latter effects raise the total $4.78 billion trade improvement to $5.23 billion or an additional $450 million. After adjustment for counterbalancing trade and financial flows and for the real output effect, this $450 million raises real output an additional $66 million to a total of $1.34 billion. In the third year, the first year increase of $697 million in real output has grown to $1.74 billion. Additionally, there is $120 million from the multiplier impact on the additional $66 million in Year 2 and $12 million from another increased real price of oil in Year 3. These total to $1.82 billion in the third year. Thus, the reduction of oil imports by 500,000 bbl/day would result in external benefits of $3.82/bbl in Year 1, $7.34/bbl in Year 2, and $9.97/bbl in Year 3.

National Risks of Supply Disruptions

Another dimension of the external benefit of reducing oil imports is decreased costs which could arise from an energy supply disruption. The United States in 1978 imported 21.6% of its total net energy and 45% of its petroleum. This dependence may adversely affect its ability to pursue an independent foreign policy and also subject the economy to the risks of supply disruptions. Such interruptions could cause lost output and unemployment that may not be recaptured later, as well as temporary backlogs and scheduling difficulties for U.S. business. Additionally, the population may suffer many inconveniences leading to altered lifestyles and economic loss. Estimating the costs to the United States of this energy dependence involves evaluating the probability that the supply disruption will occur, the extent of our foreign dependence, and the sum of the cost estimates of the three areas — national security, domestic production, and individual lifestyles.

The cost of these factors may be assessed in several ways. First, estimates could be made of the various costs of the 1973-74 oil embargo and the resulting changes in U.S. foreign policy. The cost estimate would be multiplied by an appropriate risk probability. The second approach assumes that the U.S. rationally assesses the cost of the dependence on foreign oil and then institutes policies to insure against this risk. The cost of the program is assumed to approach the perceived cost of the risk. The Strategic Petroleum Reserve (SPR) is a risk insurance program. It does not increase energy supply but simply permits the rescheduling of marketing this supply. It does not minimize imports, or balance of payments and dollar leakages.[*]

Every trade deficit is offset by an inflow of capital; the balance of payments is always equal to zero. From this relation, some argue that there is no necessary employment effect from trade deficits. However, the capital inflow may have a longer lag before employment shows up, may remain as idle balances, and may in part represent government interventions to support exchange rates. Thus, the employment effect identified in this paper appears to represent the general case.

For this entire stimulation to occur, those firms and individuals who had used oil must have access to additional domestic fuel supplies or conservation measures. If they do not, industries may be forced to shut down and lay off workers so that some of the employment and real output benefit of reducing oil imports is lost. In this regard, a quota system is not a good policy option, rather, good policy would be increased conservation or the development of gaseous or liquid synthetic fuels.

[†] Multipliers differ for each component of monetary and fiscal policy; export multipliers are generally larger. Michael Evans, "Multiplier Values and Policy Simulation" in *Macroeconomic Activity*, 557-94 (1969).

[‡] From these relationships, and the split between real and nominal output, the cost of 1% unemployment is derived. The current labor force is approximately 100 million; the marginal contribution of a 1% increase in the employment rate is $15.78 billion in real output assuming the same proportional relation holds as identified in the text.

[*] Research at the University of Chicago suggests a different perspective on the risks associated with a large dependence on imported oil. [See George S. Tolley and John D. Wilman, "The Foreign Dependence Question," *Journal of Political Economy*, 323-47 (1977) March/April.] The social demand curve for oil is more inelastic than the private demand curve. This difference becomes apparent when United States runs short of oil. The firms incur lost sales and nonoptimal production scheduling. However, the firms do not pay workers' unemployment costs nor the nation's foreign policy costs. Thus, they assume only part of the total cost and their inventories reflect an insurance policy against the risks they incur. The externalities — unemployment and foreign policy — indicate a benefit from government intervention in increasing the size of inventories held. The advantages of government development of the SPR may be offset by a reduction in the inventory holdings of private firms. The latter currently maintain a about a 3-week stock. Once the government has a 58-day inventory, the private firms may find it optimal to reduce their inventories since they are now less exposed to the risk of supply disruption. The reported cost of the SPR then does not reflect the real reduction in risk to the nation. University of Chicago researchers have estimated that the externalities amount to approximately 15% of the world oil price at the U.S. current level of dependence. Specifically, at $20/bbl, this amounts to $3.00/bbl; at $23.50/bbl the externalities are $3.53/bbl.

Various other policies may also help to avert or minimize risk. They include conservation, increased domestic output, and a shift of foreign oil dependence to more reliable countries (Canada, possibily Mexico, and Indonesia). The latter policies may also affect our balance-of-trade and dollar leakages.[*] Thus, they may be more cost-effective; this is particularly valid when the SPR results in a reduction of inventories by private firms.

This study assumes that the cost of the SPR program reflects the value society places on protection from the costs of energy supply disruptions.[†] The latest cost estimate of developing a 1 billion barrel SPR is between $20 and $25/bbl. Assuming that the SPR will be required every five years, then the annual external benefit of decreasing our imports by 500,000 barrels is $4.00/bbl (using the lower estimated cost).

Summary

In this section, the components of the externalities associated with reducing oil imports are combined and joined with the direct benefit of lower oil imports. This total (social) benefit of reduced oil imports provides insight into whether the United States has been pursuing a cost-effective energy policy. If new domestic energy sources are projected to come onstream at a higher total cost than the benefits from reduced oil imports, then the United States has pursued such a policy. A positive difference between the total benefit of reduced oil imports and the private (direct) cost of new synthetic fuels or measures to increase conservation efficiencies indicate governmental intervention is desirable. The external benefits of reducing oil imports accrue to the nation as a whole and not to the individual or firm who brings on the new synthetic fuels or the firms or households who increase their energy efficiency.

Table 2 presents the estimated per barrel external benefits of reducing oil imports. Because the impact varies over time, initial estimates are shown for the first three years. The impact of currency depreciation upon domestic inflation is projected to take two years to be fully felt, while the multiplier process involved in dollar and employment leakages takes several years. Additionally, in the second year, a larger portion of domestic oil becomes decontrolled, and its price begins to reflect world oil prices. The total external benefits in the first year from reducing oil imports amount to $22.42/bbl and rise to $38.92/bbl in the third year. In the first year, the external benefits of reducing oil imports become greater than the cost of the oil itself, indicating the encompassing and substantial nature of these externalities.

Table 2. DIRECT AND EXTERNAL BENEFITS OF REDUCING OIL IMPORTS INTO UNITED STATES BY 500,000 bbl/day

	Year 1	Year 2[*]	Year 3
	$/bbl (1979$)		
Direct Benefit			
Reduced Oil Imports[†]	20.00	20.40	20.81
External Benefits			
Improved Trade Balance — Currency Appreciation — Lower Inflation	6.44	11.89	12.45
Lower Oil Prices	8.16	11.69	12.50
Added Real Output Through Decreased Dollar Leakage	3.82	7.34	9.97
Decreased Supply Disruption Cost Due to Less Dependence	4.00	4.00	4.00
Total	22.42	34.92	38.92
Total Per Barrel Benefit	42.42	55.32	59.73

[*] In each succeeding year from Year 1, oil import demand reflects the original 500,000 bbl/day reduction.

[†] The average price of oil imports in 1979 is estimated at $20/bbl and is assumed to rise in real terms 2%/year.

Over the longer term, additional relationships and interactions among these externalities can be posited. Some may be counterbalancing. Reliance upon the series of partial equilibrium analyses becomes less appropriate and is subject to bias. For example, if substituting domestic for foreign energy results in less dollar leakage, the economy grows more rapidly, which affects our trade balance (imports may increase faster than exports) and energy prices (greater energy demand may lead to some increase in oil imports). Also, the long-term consequence of currency appreciation is the substitution of foreign for domestic goods and services, which negates some of the benefits of the improved balance of trade. Offsetting these two relationships will be the larger proportion of domestic oil and gas not subject to price controls. Thus, any policy designed to increase total energy supply or decrease demand will have a very large external effect upon the nation's total energy bill. These relations suggest that the longer-term impact is uncertain but possibly closer to the external benefits of Year 1 than of Year 2. The exception to this conclusion would occur if world oil supply becomes more inelastic in future years either because of a depletion of the resource base or because of supply-constraining political and economic policies by OPEC. Both these developments appear likely.

In July, President Carter proposed a goal of displacing 2.5 million bbl/day of oil imports by synthetic fuels and unconventional gas production and an overall reduction of 4.5 million bbl/day from these sources plus heavy oil and various conservation measures. Preliminary assessment shows the estimated external benefits of a 2.5 million bbl/day reduction would range from $21.30/bbl to $36.50/bbl in the short-term. To simplify our analysis, we postulated that the reduction would all occur in Year 1 and used current economic conditions to capture the economic repercussions. In reality, import reduction would occur gradually as new indigenous energy supplies are developed and conservation take place over an extended period, during which some of the economic relations may change. However, the short-term cumulative effect of the gradual reduction will tend to produce the effect identified in this paper.

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[*] Shifting our dependence to North American oil exporters may also result in purchasing from countries whose marginal propensities to import U.S. goods and services are higher.

[†] Whether society fails to achieve its insurance because of private firms' reduction of inventories does not negate the appropriateness of using the SPR program to assign society's values.

For the full 4.5 million bbl/day reduction, the additional 2 million bbl/day cut may have a diminished external benefit if the entire reduction occurs in too brief a period. This may result from possible bottlenecks in the economy, causing a smaller relative increase in real output, smaller dollar appreciation from additional trade improvement, and fewer national risks from supply disruptions as oil imports account for a smaller share of total energy consumed. However, if the entire 4.5 million bbl/day reduction is fairly well spaced, the first diminished external benefit need not occur, and in the 1985-90 period, a more inelastic oil supply may yield greater benefits from additional oil import reduction. Thus, external benefits similar to those estimated in this paper may accrue up to and beyond the President's original goal.

The external benefits that our nation could realize from deploying synthetic fuels and developing new technologies to increase supply and reduce demand are of great magnitude. If synthetic fuels can come onstream and meet environmental standards at a cost of under $42.42/bbl, then the United States has not been pursuing its most cost-effective energy policy. The same is true for conservation. Given that nearly half the benefits are external and do not accrue to the firm or individual producing the synthetic fuel or improving energy efficiencies, Government intervention is desirable. It may take several routes, such as subsidizing new energy supply or new conservation measures or simply levying a tax upon imported oil equal to the amount of the externalities. Such an action would raise the price of energy so that the firms and individuals would capture adequate private gains from increasing energy supply or decreasing demand.

Rod Lemon

IGT

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ENERGY TOPICS
A Periodic Supplement to IGT HIGHLIGHTS

September 1, 1980

THE EXTERNALITIES OF OIL IMPORTS REVISITED

Note from the Editor:

The October 1, 1979, issue of Energy Topics *contained an article by IGT consultant Rodney Lemon analyzing the direct and indirect costs to the United States of its current dependence on oil imports. This analysis, which assumed that a reduction of oil imports would result in lower oil prices, focused on 3 categories of economic and political externalities: the costs of inflation, unemployment, and potential supply disruptions. Together, these externalities were shown to be much larger than the direct cost of oil imports.*

As we anticipated and, indeed, hoped, the article generated a great deal of interest as we received many comments on Professor Lemon's methodology and conclusions. In the following sequel, he responds to some of these comments and elaborates on several of the points made in his earlier paper. The result of these revisions has been to increase his estimates of the total benefits of reducing U.S. oil imports — a conclusion that heightens the need for this nation to develop alternative energy-supply sources.

1. Will a reduction in oil imports actually reduce world oil prices?

Most likely, prices will be lower than the levels that would otherwise have existed. A policy of expanding domestic alternative energy supplies (including conservation) by the oil-importing nations would not necessarily cause OPEC prices to fall in constant dollars or even to stabilize, but rather to increase less rapidly.[a]

Spot-market prices may change immediately and influence the average price of imported oil. From fourth-quarter 1979 to the summer of 1980, spot crude prices fell as world demand softened due to a decrease in inventory buildup, a slowdown in economic growth, and higher oil prices.[b] This decreasing spot-market price in response to decreasing demand is exactly what the October 1 analysis envisioned when it predicted that a 500,000 bbl/day decline in U.S. imports would cause oil prices to be $0.52/bbl less than they would otherwise have been. Some reduction in the quantity supplied was also envisioned and did occur in this period.

Various assumptions have been made by energy commentators about OPEC's pricing behavior.[c] Two frequently cited are:

- **OPEC will seek to maximize the net present value of oil resources.** This motive has been used to explain OPEC's restraint in raising prices in the 1975-77 period and the conservative members' current position favoring smaller price increases. Since higher oil prices create conditions favorable to the development of alternative energy supplies in the consuming nations which would lower future OPEC revenue, the OPEC members, particularly Saudi Arabia, would increase current output to hold prices down to ensure a future market for oil. Under this behavioral assumption, several developments in 1979 are said to have caused higher oil prices. They are: 1) a perceived smaller contribution by nuclear energy, 2) perceived environmental delays in synfuel development and higher costs, and 3) the perception that the alternative to holding oil — financial resources — may not appreciate faster than inflation or oil prices, thus raising the opportunity cost on current output. This behavioral assumption indicates that a decreased demand for oil, other factors held constant, would decrease the net present value of oil but would not necessarily change the rate of production. It does not diminish the likelihood that U.S. reduction of imports will lower price.

- **OPEC will seek to maximize revenue for a given production level.** This motive is more closely related to the current economic setting than to future market conditions. Under this assumption, given an inelastic demand, OPEC will maximize revenue by limiting output and driving the price higher. While this has not been done in a fine-tuned manner (i.e., output has not fluctuated in large magnitudes with changes in demand), OPEC has not increased its output, as was expected in the early 1970's, and thus its behavior is consistent with this framework. Although OPEC has not tried to reduce output from current capacity to extract additional revenue (Iran's decrease is tied more to specific political, social, and economic factors than to oil pricing reasons), this policy could be used in the future as OPEC moves along its own learning curve in oil pricing.[d] Under this behavioral assumption, a decrease in demand would have a sizeable effect upon price.

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[a] OPEC could also reduce output to match the decrease in demand; Saudi Arabia is often said to be ready to decrease production back to 8.5 million bbl/day. But so far it has not done so, and this one-to-one correspondence is not the general case to be expected over the long run.

[b] Although the amount of oil sold on the spot market is not large, large quantities, including oil produced by OPEC members, are traded at prices approaching the spot-market price rather than at official levels. For example, *Petroleum Intelligence Weekly*, March 17, 1980, pp. 1-3, indicates that by the end of 1979, nearly 40% of OPEC's crude oil was being sold above official levels; spot trading accounted for as little as 30% of this.

[c] See, for example, the comments by William Hogan in Oak Ridge National Laboratory Overview Paper No. 1, ONEP, November 6, 1979.

2. Does not an emphasis on reducing oil imports contravene the very basis of international trade: the principle of comparative advantage?

No. The principle of comparative advantage indicates there are benefits to all countries from their specialization in international trade whenever countries possess different relative advantages in the production of different goods and services. Current U.S. dependence upon imported oil appears a logical outcome of this economic principle. However, objections to our state of dependence rest on externalities that market participants do not consider when applying this principle. Valid objections include 1) the possibility of supply interruptions which threaten the welfare and the security of the nation, 2) the very high marginal social costs resulting from higher oil prices, greater currency depreciation, and lost employment, and 3) the possibility that OPEC would extract high and arbitrary rent on oil, given the rigidities in the market and time lags in investment in alternative energy sources. Such objections, however, call for a reevaluation of our dependence rather than for autarky. We should be mindful that the benefits from imported oil may still outweigh the costs at some reduced level of dependence and that trade patterns are determined by the relative advantages and disadvantages of *all* goods and services, not just one item. The principle of comparative advantage and trade patterns should be based upon the relative incremental social costs of production of various goods and services.

Placing a premium on imported oil equal to the net external costs and then letting market forces determine the degree of this nation's dependence on oil appears desirable. Dependence can be expected to lessen under such a policy as imported oil costs to U.S. consumers rise. The terms of trade would change to the advantage of the U.S. once the premium is added. Given OPEC's relative abundance of oil with low production costs and our advantage in high-technology goods, trade appears mutually desirable. However, without greater domestic energy supplies, the consuming nation has little leverage over oil pricing, and the benefits of trade may reside inequitably with the producer nation.

3. Were the costs associated with actual or possible supply disruptions fully estimated?

A reevaluation suggests not: External costs are more likely $13.50/bbl, considerably higher than was reported earlier. The costs of possible or actual supply disruptions of an imported commodity increase with 1) greater dependence, 2) greater necessity, and 3) lower supply reliability. In the case of oil, the United States is currently exposed to high costs in all three areas. These high costs show up in 1) reduced national security, 2) unemployment, inflation, and lost and postponed production, and 3) altered lifestyles.[e] Reduced national security is a cost that is continually incurred whether an embargo occurs or not. The economic costs to producers, resource owners, and consumers are largely incurred when an embargo actually occurs rather than in altered behavior in anticipation of a supply disruption.[f] Further, whereas producers, resource owners, and consumers are able to recoup some of their losses in later years, the damage to national security is not so easily remedied. In fact, continual reduced national security has compounding effects.

Reduced national security is the most serious of the costs and also the most difficult to quantify.[g] Various macroeconomic models of the United States, with the assumption of oil embargoes, permit the estimation of the costs of reduced real growth, unemployment, and higher inflation.[h] The costs to consumers of altered lifestyles has also been measured in several microanalyses of individuals in particular geographical locations or with respect to consumption of one particular product.[k] While none of these costs is easily measured, the costs in each area can be lessened by the existence of strategic buffer stocks, increased alternative energy supplies, and increased efficiency in energy use. Such programs may be highly cost-effective. For example, Data Resources, Inc. (DRI) has estimated that the first-year GNP loss in 1972 dollars from a 6 million bbl/day embargo lasting one year when no buffer stock exists would be $238.5 billion.[m] A 750-million-barrel reserve would reduce the loss to $104.5 billion, while a 1-billion-barrel Strategic Petroleum

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[d] Alirio A. Parra of Venezuela posits that the exporting countries' production decisions are made "with priority given to extending the life of the resource base and to assuring that economic development is at a pace that societies can absorb." See: A. Parra, "The World Oil Market: An Exporter's View," *Journal of Energy*, January 1980, pp.55-62. However, contrary to Parra's view, market forces were more powerful than oil exporters' goals as evidenced by oil prices in 1979.

[e] Altered lifestyles refer to changes in consumer behavior. A supply disruption may lower consumers' level of satisfaction, as in the examples of a consumer who has to rise at 6:00 a.m. to get in a gas line or the prevention of some weekend travel by Sunday closings of gas stations.

[f] Firms may increase their stockpiles, or change production technique from least cost to higher cost but less risk; in these cases, short-term costs are rising.

[g] Among others, see Arnold E. Safer, "Employment and Energy Independence," presented at the National Summit Conference for Energy Leadership, Reston, Virginia, 1976. Safer states that "the greatest cost of imported oil is not economic, but political. It has meant the decline of U.S. influence around the world, the setting of unacceptable constraints on our foreign policy, and the erosion of our long-standing alliances."

[h] Ronald M. Whitfield and Sara Lynn Johnson, "Iran: Potential Trouble Again," *DRI Review*, December 1979, and Wharton Econometric Forecasting Associates, Inc., *Simulation Study of Eight Petroleum Supply Disruption Scenarios*, DOE/EIA, HCP/15725-01, April 1979.

[k] For example, T. M. Reid, in the *Washington Post* reports on a DOE estimate for the Washington Metro area of the consumer losses from the oil embargo in 1974.

[m] DOE/EIA, *Macroeconomic Effects of Petroleum Supply Interruption*, Volume 1, March 1979, p. vi.

Reserve (SPR) would reduce the loss to $69.5 billion. The severity of an embargo decreases more than proportionally as the magnitude of the curtailment lessens. The marginal benefit of the last 250 million barrels of buffer stock in this scenario is $139 a barrel, which is far higher than its projected cost.

The real benefits of reducing oil imports can be determined by evaluating the costs of the next best alternative, which several studies consider to be the strategic petroleum reserve (SPR).[n] However, for several reasons the SPR is not a perfect substitute for imports: It may not be able to respond to repeated disruptions; exporters and other importers may place constraints on the creation of a very large SPR by the United States; economic inefficiencies may arise from the change in allocation channels and the nation's lack of perfect foresight on the use of the SPR; and when the disruption is politically motivated, its size may be determined by the size of our SPR.

Given these perspectives on the costs of supply disruptions, the methodology in the previous study underestimated these external costs in several areas. First, reducing oil imports has several advantages over an SPR. Second, national security costs are large and must be included together with production costs. Third, a supply disruption is likely to occur more than once in five years.[o] On the other hand, my earlier methodology overestimated external costs in two areas. New domestic energy supplies, which can replace oil imports, may not permit a one-barrel reduction in the SPR for each barrel of new domestic output. Second, although the marginal operational costs of the SPR are unknown for the entire buffer stock, this marginal cost is likely to be lower than the "current low estimate of the average total cost" used in the initial study.

To re-estimate the external costs of high dependence upon oil with respect to actual or potential supply disruption costs, the degree of risk-exposure to supply disruptions the United States faces even after it has built a one-billion-barrel SPR was first examined. An SPR of this magnitude will decrease the costs of an embargo and the likelihood that one will occur. Quantification of this exposure depends upon many factors, including the variables that are considered by the oil-exporting countries and their strategies, which are difficult for us to know.[p] Subjectively, the one-billion-barrel SPR was judged to reduce exposure by 70 percent — an assumption that changes the assumed incidence of an interruption to one every 10 years — and to lower appreciably the actual and potential damage of disruption.

The second factor in the re-estimation concerns the supply-disruption costs of embargoes and their possibility, assuming the existence of a one-billion-bbl SPR. Future supply disruptions, such as embargoes, are not monolithic. Embargoes can come in many forms, and differences in their costs reflect their size, duration, the countries embargoed, the ability to draw down strategic buffer stocks, and assumptions about the world petroleum market. Rather than estimate a weighted average cost based on each variation, this analysis has selected a mid-range supply disruption as representative and estimates the cost to the United States of this mid-range embargo; specifically, an embargo of 4 million bbl/day that lasts one year is imposed against the United States, and comparable embargoes are imposed against our major trading partners. The U.S. has a 1 billion barrel SPR drawn down at the rate of 2.74 million bbl/day and imposes petroleum allocation regulations and domestic price controls for crude petroleum and products. This 4 million bbl/day embargo with a 2.74 million bbl/day SPR is among the less severe supply interruptions which DOE has evaluated using the macroeconomic models of DRI and Wharton Econometric Forecasting Associates, Inc. (WEFA).

The curtailment of petroleum supplies has long-range effects upon the economy which last many quarters after the cessation of the embargo. In five to eight quarters, annual increases in real GNP tend to rise above the increases projected had there been no curtailment; however, the simulations by WEFA and DRI indicate that most of the GNP is not made up in later periods. The greatest economic cost of an embargo is lost rather than postponed output. Assuming a discount value of 10%, the present-period-discounted value of the averted lost and postponed GNP due to a marginal increase in strategic buffer stocks is $73.35/bbl in 1980 dollars.[q] The annual benefit assuming that an embargo of this magnitude occurs every ten years is $7.33/bbl.

Of the three components of supply disruption costs, national security was hypothesized as presenting the greatest costs.[r] However, because of the conceptual complexities, this study conservatively assumes that national security costs are the same as the annual economic costs. The cost of altered life styles was not quantified. Thus, the annual remaining external benefit from decreased exposure to oil imports even after creation of a one-billion-barrel reserve amounts to $14.67/bbl.

The marginal operational cost of a one-billion-barrel SPR is unknown. The SPR currently holds about 100 million barrels and withdrawal facilities are not yet complete. Phase I of the SPR program has a goal of about 250 million barrels and an estimated average cost of $3.47/bbl. Considering that the best storage sites were chosen first, the average and marginal

[n] Supply disruption costs were based on the cost of the SPR in the October 1 *Energy Topics* analysis. This methodology was also used in Schurr's *Energy in America's Future* and in other analyses.

[o] In the past six years, the United States has been exposed to two supply disruptions. National security experts now estimate the chance of a serious cutoff of Mideast oil at about 75 percent. Alvin Alm, quoted in *The Energy Daily*, July 8, 1980, p.3.

[p] Yoram Kinberg and others, "Energy Buffer Stock Decisions in Game Situations", in *Energy Policy Studies in Management Sciences*, Volume 10, North-Holland, 1979.

[q] This marginal impact is based upon an average of the results of the DRI and WEFA models from the difference in GNP over the three-year period when a 2 million bbl/day embargo occurs with no SPR and when a 2 million bbl/day SPR exists. This marginal impact is lowest of the results reported by DOE and is assumed representative of the specific mid-range embargo this study considered.

[r] This general premise is supported by the current thinking of the research project on National Security and Energy at Georgetown University.

costs can be expected to rise in real terms. Estimates of operational storage costs in New England, the Middle Atlantic states, or the Southeast, presented in early Congressional hearings, were approximately $6.00/bbl and may represent good estimates of the marginal operational cost of a one-billion-barrel SPR.[s] Its annual marginal operational cost would then be $0.60/bbl assuming an embargo occurs only once every 10 years.

The advantages of increasing domestic energy supplies include a reduction of our need for an SPR and a lowering of supply-disruption costs. To avoid double accounting, only the marginal improvement in supply disruption costs from the additional barrel of new domestic supplies compared with a barrel of oil stored in the SPR was added to the reduced costs of maintaining a smaller SPR. The hypothesized one-billion-barrel SPR covers fully the one-billion-barrel exposure that remains from a one-year disruption when it is assumed that one-half of our normal imports of 3 billion bbl/year will continue to arrive, that conservation could be increased by 5 percent, and that domestic oil output also expands by 5 percent.[t] Then, an additional 500,000 bbl/day (182.5 million bbl/yr) of domestic supply would permit a 91.25 million-barrel decrease in the SPR. Using this ratio, a saving of $0.30/bbl could be realized in lower SPR costs.

The reduction in supply disruption costs rests on the four factors cited earlier, which implied that a barrel of domestic supply is preferred to a barrel of SPR with respect to minimizing disruption costs. Quantitatively, both DRI and WEFA simulations of oil supply disruptions show a surprisingly large "overhead" cost from the inefficiencies of the Mandatory Petroleum Allocation Regulations that approach 90% of this study's estimated benefits of an additional barrel of buffer stock.[u] The other three factors have not been quantified. Offsetting these advantages is the possibility that the new supplies may be used to replace oil imports which would not have been embargoed. Assuming these non-quantified factors counterbalance each other, this study finds that the marginal net benefit of new energy supply which replaces a barrel of buffer stock is $13.20/bbl (i.e., .9 × $14.67/bbl).

Adding these two components, the external benefit with regard to reducing supply-disruption costs is $13.50/bbl for new energy supplies. This cost estimate considerably undervalues — possibly by a factor of 8.25 — the current benefits of additional supply given that our SPR is still in its infancy.[v] Thus, this cost estimate is more consistent with long-term benefits.

4. Have economic conditions or further analyses altered the October 1 estimate of the direct and indirect benefits of reducing oil imports?

Yes, OPEC has significantly increased the direct cost of oil, and other countries exporting to the United States (principally Canada and Mexico) have followed OPEC's lead. The higher cost of oil increases the external benefits both through the oil price effect and through the net trade balance, which influences the currency values and real output. The revised direct and indirect benefits of reducing oil imports by 500,000 bbl/day are shown in Table 1.[w]

Table 1. DIRECT AND EXTERNAL BENEFITS OF REDUCING U.S. OIL IMPORTS BY 500,000 bbl/day

	Year 1	**Year 2**	**Year 3**
	$/bbl (1980)		
Higher World Oil Price Scenario			
Direct Benefit			
• Reduced Oil Imports[a]	37.00	37.74	38.49
External Benefits			
• Lower Oil Prices	12.32	17.71	18.98
• Improved Trade-Currency Appreciation — Lower Inflation[b]	11.19	20.41	21.18
• Added Real Output[b]	6.60	12.70	17.13
• Decreased Supply Disruption Costs	13.50	13.50	13.50
Externality Subtotal	43.61	64.32	70.79
Total Per Barrel Benefits	**80.61**	**102.06**	**109.28**

a The average price of oil imports is assumed to rise 2%/yr in real terms.

b OPEC has decreased its propensity to import this past year, and Bankers Trust expects this lower propensity to continue in the near term. This tendency may raise the cost of these two externalities above my estimate. See Bankers Trust Company, *Energy Viewpoint*, March 9, 1980.

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[s] *Review of the Strategic Petroleum Reserve Plan*, hearing before the Committee on Interior and Insular Affairs, U.S. Senate, February 4, 1977, Pub. No. 95-10, pp. 252-255.

[t] This disruption is similar in magnitude to the mid-range 4 million bbl/day considered earlier except that the DRI and WEFA simulations did not consider increased domestic oil output nor conservation. Had a more severe disruption been posited (i.e. three-quarters of our normal imports), the SPR would provide less coverage.

[u] An average of DRI and WEFA results shows that a 2 million bbl/day disruption lasting one year with buffer stocks of 2 million bbl/day such that no shortfall occurs would still result in a $23.6 billion (72$) decrease in GNP.

[v] Our SPR is currently so small that any decrease in oil imports will not reduce the need for the SPR. Further, given the absence of a large buffer stock, both the incidence and seriousness of a supply disruption increase by factors of 3.3 and 2.5, respectively. The incidence factor was derived by assuming a 70% reduction in the probability of an embargo due to a large buffer stock so that a 30% risk remains. The seriousness factor was based on the marginal cost of a one-year, 4 million bbl/day disruption with no buffer stock of approximately $68 billion/million bbl/day — slightly more than 2.5 times the $26 billion/million bbl/day with a 2.74 million bbl/day buffer stock. These estimates are again based on an average of DRI and WEFA simulations. This high cost is often cited as justification for a synfuel or conservation program without regard to the macroeconomic costs identified in other sections. This research indicates the need for a large buffer stock. The remaining oil supply disruption costs added to the other macroeconomic and oil price effect costs then speak for a program of enhancing domestic energy supply.

[w] The assumptions on the price elasticity of oil supply and demand in the October 1st analysis were retained. U.S decontrol of oil was considered to be one year further along, and oil imports and domestic output were based on the average levels for the first four months of 1980. These new quantities, the new price scenario, and use of the October 1 methodology result in a 79¢/bbl reduction in oil prices and the other benefits identified in Table 1.

This oil price scenario starts at the current OPEC ceiling price and may reflect oil prices under normal economic growth conditions. Further, this price scenario may be the most appropriate one for evaluating the cost-effectiveness of new energy supplies. The externalities were also analyzed under two imported oil price scenarios more reflective of the current recessed market trend. Under a $28/bbl imported oil price scenario, the first- and third-year externalities were, respectively, $36.07/bbl and $56.68/bbl. Had a $32/bbl oil price been chosen, these two externalities would be $39.41/bbl and $63.01/bbl. The externalities rise almost proportionally to the increase in the direct cost of oil imports, and, for the range of prices considered, are always greater than 100 percent of the direct cost of imported oil.

The October 1 analysis identified several linkages by which energy imports and prices affect the U.S. economy. A recent analysis by Allen Jacobs compared the results of a simple general equilibrium model in which only energy affects the economy with results from the Hudson-Jorgenson Model which also includes economy-energy interactions.[x] Use of the latter model raised the macroeconomic costs of higher import prices by 31.6%. There is good common sense underlying this finding: Higher energy prices raise world inflation, which causes further increases in energy prices, and so on. To integrate Jacob's findings with this analysis, the long-run macroeconomic costs (inflation and real output), which were identified in the October 1 analysis as probably best approximated by the first-year estimate, should be raised by a factor of 1.2, yielding a long-run total externality of $47.17/bbl.

Even after the preceding revisions, there is still reason to believe these estimates are on the low side. Examination suggests there is an array of subtle inter-linkages that are not yet included in my analysis nor in the major macroeconomic models. My analysis also assumes the existence of a petroleum buffer stock of a magnitude that simply does not yet exist and may carry political costs to acquire.

5. Can the impact of oil imports be isolated from other factors which affect the economy?

Yes, but not with complete confidence because of the complex and multifaceted interlinkages among the causal factors. A viewpoint frequently expressed in the economic literature is that energy presents a central constraint on macroeconomic policy.[y] Other writers, while not disagreeing with the importance of energy, avoid quantification by stating that energy imports cannot be separated out with any confidence as causes of the state of the economy.[z]

These complex linkages include the disturbances to which an economy is subject (weather, technological change, international upheavals, changes in consumer preferences, etc.), structural characteristics (formation of expectations, power of interest groups, wage-price framework), and the policy response of government. The interaction among these variables determines inflation, employment, and growth. To isolate and measure only the shock caused by higher imported oil prices and increased national dependence is clearly difficult.[aa] Yet, an increase in oil imports from $4.3 billion in 1972 to a probable $87.6 billion in 1980 is hardly a minor item. Mork and Hall's analysis of the 1974-75 recession claims that "at least two-thirds of the total decline in real output from the trend that occurred in those two years" was due to the energy price shock.[bb] George Gols has concluded that OPEC's 1979 spring price rise will add 3 to 4 percentage points to the U.S. inflation rate and lower GNP by 1 to 2 percentage points.[cc]

The shock of higher OPEC oil prices reverberates throughout our economy, with effects on the balance of trade, prices of domestic energy, and wage-price escalations that go beyond simplistic calculations of the percentage of GNP accounted for by foreign oil and the percentage increase in its price. But caution must be used, for some causal forces could easily be omitted from an analysis, the effects of which could be wrongly assigned to higher oil prices.

The previous analysis used conservative estimates of the impact in order to minimize possible upward bias. But the analysis nonetheless does try to quantify the impact since these secondary effects appear substantial. To avoid quantifying because of uncertainty leads to the greater sin of failing to indicate the true magnitude of the costs of oil-import dependence.

6. Is the emphasis on oil imports as a cause of trade deficits (as opposed to other imports or U.S. exports) misplaced?

Yes and no. Oil imports have seven characteristics different from most other imports which require unique treatment. At the same time, oil imports are only one aspect of the United States' problems with respect to its balance-of-trade and current-account deficits. Although a reduction of oil imports can contribute to a positive balance of trade, it should be evaluated against the benefits of increased competitiveness of our export industries.

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[x] Allen Jacobs, "An Evaluation of the Benefits of Reducing Imports by 1 MMBD," Unpublished Draft, DOE, 1979.

[y] William D. Nordhaus, "The Energy Crisis and Macroeconomic Policy," *The Energy Journal*, Vol. 1, No. 1, January, 1980, pp. 11-19.

[z] Hans Landsberg and others, *Energy — The Next Twenty Years*,. Cambridge: Ballinger, 1979, pp. 155-159.

[aa] Some people have pointed to the experience of West Germany and Japan as an indication that oil imports are not a factor affecting the U.S. economy since these countries have had lower inflation rates and stronger currencies together with a higher dependence on imported oil than the United States. While the reasons for these relations are complex and multifaceted, it is important to note that world oil is priced in U.S. dollars and the dollar has been declining relative to the mark and the yen. In fact, the large oil price increases in early 1979 together with the strengthening of the U.S. dollar relative to the yen are major factors contributing to a 10-point increase in Japan's inflation rate from January to July last year. Similarly, the fall of the dollar with respect to the yen and the mark caused the real price of oil in Japan and Germany in 1978 to be lower than it was in 1974.

[bb] Knut A. Mork and Robert E. Hall, *Energy Prices, Inflation, and Recession, 1974-75*, MIT-EL 79-028 WP, Revised May, 1979.

[cc] George Gols, "OPEC Prices and Impact Upon U.S. Economy," Arthur D. Little, 1979.

The seven unique characteristics of oil imports are the following: 1) They are paid for in U.S. dollars. Thus, any policy which increases the value of the dollar also increases the revenue of the oil exporter, who stands to benefit fiscally if the United States lowers its oil dependence and strengthens its current account position. 2) Oil producers have indicated that they would like to decrease their rate of production. 3) Characteristics 1 and 2 indicate that retaliation costs would not be likely if the United States raised import duties on oil. 4) Oil is a nonrenewable resource and has a high opportunity cost if production is not timed correctly. 5) The elasticities of both demand and supply in the short term are extremely small. The marginal cost of the last unit exceeds the average price paid, which leads to possible overconsumption. 6) The market rigidities and investment time lags needed to develop new energy supplies leave the United States exposed. The seriousness of exposure depends on the reliability of supply. 7) The supply of oil imports is subject to disruption for political and economic reasons.

These characteristics suggest that the argument for some form of government intervention in the case of oil imports should *not* be generalized to apply to all imports. However, as a technically-advanced country, the United States must weigh the relative advantages from developing its export potentialities (which include energy technologies and supplies) compared to expanding its domestic energy supplies. More exports would strengthen the current account and the value of the U.S. dollar. Thus far, Japan and West Germany have successfully pursued such a policy, while the United States, due to higher inflation rates, low productivity growth, and other factors, has not. West Germany is now moving to increase domestic energy supplies which would substitute for oil and the government plans to assist in the construction of a number of coal gasification and liquefaction plants. Not only will the new synfuel industry decrease West Germany's oil dependence, but West Germany also plans to export its coal-processing technologies.[101]

The energy policy of the United States should therefore be part of a broad-based economic policy. Given the large marginal advantages of reduced oil dependence, this economic policy would include specific requirements for increasing domestic energy supplies as well as improving U.S. technological superiority, labor productivity, etc.

7. Can macroeconomic policies reduce the costs of inflation and unemployment associated with our large dependence upon foreign oil?

Not entirely, since dependence on foreign oil places constraints on both monetary and fiscal policies. Further, it is easier to posit than to institute correct monetary and fiscal policies in response to larger oil import bills.[96] The October 1 paper was based on the assumption of a relatively steady economic policy.[97] The following survey of alternative economic policies suggests that they may not reduce costs below those estimated in my previous analysis and some alternatives may in fact increase costs. Again there is uncertainty in this evaluation of economic policies because of our imperfect knowledge about the effects of policies and disagreements about their efficacy.

Some economists propose an increase in money supply to offset the net dollar outflow caused by larger oil imports or their higher prices. They argue that without such an increase, the prices will decrease real money supply and raise interest rates, which will depress economic activity.[98] However, over time the growth of money supply is well correlated with inflation, and increasing money supply to prevent rising interest rates will generate higher inflation and the expectation of it. This will lead to further currency depreciation, higher prices, lower real money supply, expectation of higher nominal interest rates, and higher interest rates.[99] Thus, caution must be used in suggesting that an accommodating monetary policy can prevent the costs of increased oil imports or their higher prices from affecting the economy.

To offset the wage-price spiral initiated by higher oil prices and inflation from currency depreciation via trade deficits, some policy analysts call for wage-price controls.[100] This spiral has intensified in recent years as more labor contracts contain cost-of-living clauses, minimum floors are indexed, and interest rates are more flexible. Yet, wage-price guidelines rigidly followed have been found to cause misallocation of resources and inequities (externalities of a different type) and by themselves do not treat the causes of the higher prices.

A third proposal to offset the new dollar outflow is fiscal stimulus through tax cuts or government spending increases. Government deficits, however, must be financed. Government borrowing crowds out private investment and drives up interest rates while open market operations and printing money turns this policy option into the increased-money-supply alternative discussed earlier. Mork and Hall's review of policy options found positive benefits from those policies that are pro-investment, such as tax cuts.[mm] Yet the benefits from tax cuts have existed irrespective of the state of oil dependence, and, had tax policies been more enlightened, these benefits, which offset larger oil imports or their higher prices, would not be so readily apparent.

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[101] Japan's Ministry of International Trade and Industry has proposed industries with the best growth potential which will be eligible for official financial assistance and incentives. The new group for the 1980's includes energy industries, among them coal gasification and coal liquefaction. See *Business Week*, June 30, 1980, pp. 118-119.

[96] There are several reasons for this. First, there are the administrative delays in perceiving the magnitude of the oil price impact, responses in the international financial markets, price changes in the U.S., etc. Second, there are operational delays in passing policy and lags in policies' effects on the economy. Third, market conditions may change faster than policy, yielding the wrong policy for current conditions and the probability of additional externalities. Fourth, some economists question whether federal policies can be effective given market participants' anticipations and actions in light of these policies.

[97] The earlier analysis did not assume that the Government undertook any [illegible] monetary or fiscal policies to offset the [illegible] dollar outflow. The only exception was the reliance on [illegible] analysis, which noted that the money supply may not have been held constant in computing the effect of currency devaluation upon domestic inflation.

[98] The October 1 analysis [illegible]

[99] Most macroeconomic models show that a restrictive monetary policy to lessen the rise in prices will generate considerable unemployment and decreased real output before having a positive impact upon prices. This restrictive monetary policy would thus have additional direct and indirect costs over those estimated in my earlier analysis.

[100] Higher oil prices and trade deficits tend to reduce domestic demand and create unemployment, resulting in a decreased ability of workers to gain higher wages. In the U.S. wage-price setting, wages and prices are likely to rise while unemployment grows in response to larger oil imports and their higher prices.

8. Does not the equivalent of $42.00/bbl for high-Btu gas from coal cited in your previous study add to U.S. inflation?

Not any longer, in view of the OPEC price increases that have occurred since then. The cost of imported oil to the United States at the margin is $37/bbl.[nn] Although oil is priced lower than SNG on a Btu basis, the additional demand for oil increases pressure for higher oil prices, yielding an external effect of $12.32/bbl and raising the cost of oil to $49.32/bbl. Further, the additional imports add to the U.S. trade deficit, causing dollar depreciation and higher domestic prices; this results in an additional external cost of $11.19/bbl and brings the cost of oil to $60.51/bbl. Besides lowering inflation, the additional SNG will increase domestic employment, valued at $6.60/bbl, and improve national security, valued at $13.50/bbl. Thus, as long as the levelized annual cost of SNG is under $80.61/bbl, the United States will benefit. If SNG should come on at $80.61/bbl, some higher inflation would be observed but the higher prices would be offset by employment and security gains.

9. Should point estimates rather than a range be used to describe social costs over which so much uncertainty exists?

Point estimates taken by themselves imply precision and thus appear inconsistent with high uncertainty. On the other hand, when every assumption is identified and its underlying basis specified, point estimates are meaningful. Some of the assumptions were based on a widespread understanding of current and future economic conditions and past empirical regularities, but others did not have such a firm basis. However, even though there is uncertainty in trying to specify the future economic social and political setting, the analysis is documented so that the reader can drop an externality or change some parameters to reflect his own perceptions. The reader can thereby develop his own range for the externalities associated with oil imports. The parameters in these analyses were chosen with one rule of thumb: Select coefficients that understate rather than overstate the magnitude of the externalities.

The reader should also recognize that even ranges are value-laden and may be misleading unless probabilities are attached. The choice of a range requires making a judgment about issues that also involve uncertainty. Recent major writings on oil and the U.S. economy all identify factors which this study has quantified. The position was taken that a mid-range point estimate is of the most value provided that the reader is given adequate information about the manner in which these estimates are derived.

10. What kind of consensus exists among energy economists on the magnitude of the externalities from the current level of U.S. oil imports?

The externality issue has been examined in three major energy policy books and two articles published in 1979 and in several sequels. The findings of these studies are summarized in Table 2.

Table 2. COMPARATIVE ANALYSIS OF ESTIMATES OF OIL IMPORTS EXTERNALITIES

Analysis	Estimated Externality
Stobaugh and Yergin, *Energy Future*	$10-$100/bbl[a]
Landsberg, *Energy — The Next 20 Years*	Less than 100% of the direct cost[b]
Schurr, *Energy in America's Future: The Choices Before Us*	No Quantitative Estimate[c]
Lemon, *Externalities of Oil Imports Revisited*	$43-$70/bbl
Nordhaus, *Macroeconomic Impact of the Energy Problem*	$15-$75/bbl[d]

[a] New York: Random House, 1979. Stobaugh and Yergin estimate only the oil price effect quantitatively ($5.00/bbl decrease in price for a 2 million bbl/day change in U.S. import demand) and simply add a wide judgmental range for other macroeconomic externalities. The oil price effect is comparable to that estimated by Lemon and Nordhaus. In a July 31 *Wall Street Journal* article, Stobaugh and Yergin updated the external effect to $28-$68/bbl, assuming the direct cost of imported oil is $32/bbl. On top of this are "significant" political and security costs.

[b] Landsberg's group stops short of advancing their own estimates. However, the following can be inferred. An oil price externality of $0 to $25/bbl is identified, with $2/bbl viewed as most likely. Long-term reduced real growth amounts to approximately $10/bbl, and the supply disruption costs add possibly 10% of the cost of oil imports, or $2.80/bbl. A large jump in oil prices, such as 50%, may pose large macroeconomic costs. Specific numerical estimates were not proposed due to the limited knowledge concerning current energy-economy relations and the belief that these current relations are subject to change.

[c] Washington: Resources for the Future, 1979. Schurr offers only a quantitative estimate of the supply disruption costs to national security and economic welfare — an import tax of $2 would be appropriate. The other areas are identified, but no quantification is carried out.

[d] May 1980. Nordhaus omitted economic welfare and national security costs due to supply disruptions and their probability. In his earlier paper, *Energy Crisis and Macroeconomic Policy*, Nordhaus estimated the externalities at $13-$46/bbl. He is the only author who includes in his upper range an externality for economic policy mismanagement (which may reflect his tenure on the Council of Economic Advisors).

All five studies are in general agreement over the major kinds of externalities associated with oil imports: an oil price effect, a macroeconomic effect, and supply disruption costs. They agree that while short-run costs are likely very substantial, these costs will decrease over time as factor substitution takes place and non-OPEC energy supplies (including conservation) are increased. The short-run oil price impact may be substantially greater than any of the cost estimates shown in Table 2[oo], yet none of the studies uses this extremely high externality in its analysis. On the macroeconomic effects, several studies have found the causal factors to be so intertwined that quantitative analysis of the impact cannot be assigned with certainty. Landsberg's lower estimate rests largely on an estimation of the long-term macroeconomic costs of reduced real growth, while Stobaugh and Yergin, Lemon, and Nordhaus estimate the macroeconomic costs based on more near-term relationships. The last three studies, which calculate externalities over similiar periods, also give somewhat similar estimates. Notes to Table 2 indicate some of the differences in the methodology used to derive the estimates. The results of the three studies which offer near-term estimates of the externalities suggest that a subsidy of $30/bbl is probably warranted, plus or minus the net externalities of the replacing source.

[mm] Knut Anton Mork and Robert E. Hall, *Macroeconomic Policy Response to the 1979 Energy Price Shock*, presented at CEPR Conference, Cambridge, Mass. November 7-8, 1979.

[nn] The reader should refer to Table 1 in this paper for the specific numbers used. First-year costs are used; these are the most conservative given the approach employed.

[oo] William Nordhaus suggests that the short-term oil price impact from a marginal change in demand can be calculated by dividing the original oil price by the absolute value of the price elasticity of oil demand.

11. Should government intervention be circumscribed?

Yes; certain principles must be followed to minimize misallocation of resources by government action. A review of past major energy policies yields the conclusion that government intervention has generally been counterproductive.[pp] The reason lies in the political process by which laws are established and administered. The presence of a net externality is not in itself a sufficient justification for government intervention. The costs of correction, including the costs added in the legislative compromise process and in actual administration, must be less than the cost of the externality. The propensity to mismanage areas of public policy lends credence to the principle that if externalities are small, it is best that the government not enter.[qq] Nonetheless, certain government policies, such as an import tax upon crude oil and refined petroleum products, need not produce externalities provided that such a tax is of the right magnitude. An import tax that will cause higher prices — while economically sound — does involve political risks, as exemplified by the fall last year of the Clark government in Canada following a no-confidence vote over the introduction of a similar policy. The political risks hinge upon society's value of what policy is equitable.

The determination of a second-best program for minimizing governmental externalities is difficult. Such a program could involve a modest tax upon oil imports and a well-designed subsidy program for new domestic supplies. Detailed structuring of an energy program is, however, inevitably controversial and its effectiveness a matter of uncertainty, even among experts. Thus the government should only structure the broadest outlines of a program and leave the detailed structuring to the market.

Government intervention in energy matters is justified for two reasons: first, to reduce technological, environmental, and value-judgment uncertainties when the resolutions of these uncertainties have substantial external benefits; second, to reduce dependence on an imported resource. The first calls for governmental assistance on a very broad front for research and development into different fuels and technologies as well as general research.[rr] The second requires that some production goals be set and achieved with the help of government subsidies — provided that the cost of the new energy supplies (including the subsidies) remains below the social cost of imported oil. If this level of subsidies does *not* bring forth new supplies, then imports are cost-effective. To ensure that supplies are forthcoming that otherwise would not be and to lessen the potential size of the subsidy program, the government should specify an array of new fuel sources which would qualify for subsidies.[ss] Which technologies would receive these subsidies would be determined through competitive bidding schemes based on both dollar bidding and evaluation.

Summary

This re-analysis of the externalities associated with oil imports reaffirms the major findings of the first study. First, the current externalities of oil imports are large even after several favorable assumptions are made, including the existence of a large buffer stock and enlightened monetary and fiscal policy. Second, the large externalities of oil imports call for increased domestic supplies, including conservation, if they are cost-effective based on marginal social costs. Third, a corrective public policy could involve oil-import taxes and the subsidization of new domestic energy sources without large government externalities.

In July 1979, President Carter proposed a goal of displacing 2.5 million bbl/day of oil imports by synthetic fuels and unconventional gas production and an overall reduction of 4.5 million bbl/day from these sources plus heavy oil and various conservation measures. In March 1980, he proposed a $4.85/bbl tax on imported oil. Both these measures are consistent with the general findings of the analyses. Their efficacy and correctness depends on the future energy balance in the United States and the world oil market. Despite the uncertainty surrounding each relationship, the correct answer given the lag in investment time needed to bring on new supplies will not be known until it is too late. Further, given the ability of foreign producers to extract a premium, reasonable doubts should be resolved in favor of new supplemental supplies.

Rod Lemon

[pp] See Walter J. Mead, "The Performance of Government in Energy Regulations," *American Economic Review*, Vol. 69, No. 2, May 1979, pp.352-356. Mead defines the goal of public policy as optimal resource conservation.

[qq] Since energy markets have not been without substantial government intervention, conditions without government can only be conjectured. Left to market forces, energy prices would have been driven higher, resulting in reduced demand and increased supplies of both conventional and unconventional fuels. Thus, the United States would have had lower foreign dependence, and, importantly, lower external costs associated with these oil imports.

[rr] Government's attempt to lessen uncertainties may also entail some externalities. As the government tries to ensure that its research and development funds do not simply replace what the private sector would otherwise have done, it may fund more exotic technologies far from the stage of commercialization. Cost-effective research funds may be better spent on bringing some new fuel sources into the commercial stage.

[ss] Conventional oil and gas would not receive subsidies because of the difficulty in determining what would otherwise have been produced and the perception of producers' gains as inequitable.

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